US007253861B2

(12) **United States Patent**
Niiyama et al.

(10) **Patent No.: US 7,253,861 B2**
(45) **Date of Patent: Aug. 7, 2007**

(54) **LIQUID CRYSTAL OPTICAL ELEMENT COMPRISING A RESIN LAYER HAVING A SURFACE HARDNESS OF B OR LESS**

(75) Inventors: **Satoshi Niiyama**, Yokohama (JP); **Noriko Suehiro**, Yokohama (JP)

(73) Assignee: **Asahi Glass Company**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/028,787**

(22) Filed: **Dec. 28, 2001**

(65) **Prior Publication Data**

US 2002/0126229 A1 Sep. 12, 2002

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/847,333, filed on May 3, 2001, now Pat. No. 6,674,494.

(30) **Foreign Application Priority Data**

Dec. 28, 2000	(JP)	....	2000-402045
Sep. 19, 2001	(JP)	....	2001-285979
Dec. 6, 2001	(JP)	....	2001-372802

(51) **Int. Cl.**
G02F 1/1337 (2006.01)

(52) **U.S. Cl.** **349/123**; 349/35; 349/179; 349/130; 349/132

(58) **Field of Classification Search** 349/35, 349/123, 124, 133, 93, 138, 130, 175, 177, 349/185, 186, 132, 122, 126, 106, 179
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,278,328 A * 7/1981 Mukoh et al. 350/349

(Continued)

FOREIGN PATENT DOCUMENTS

JP 57-078518 5/1982

(Continued)

OTHER PUBLICATIONS

Nissan Chemical Industries, Ltd., 2pp., "Aligning Layer for Ferroelectric/Antiferroelectric Liquid Crystal RN-1266 and RN-1286" (w/English Translation).

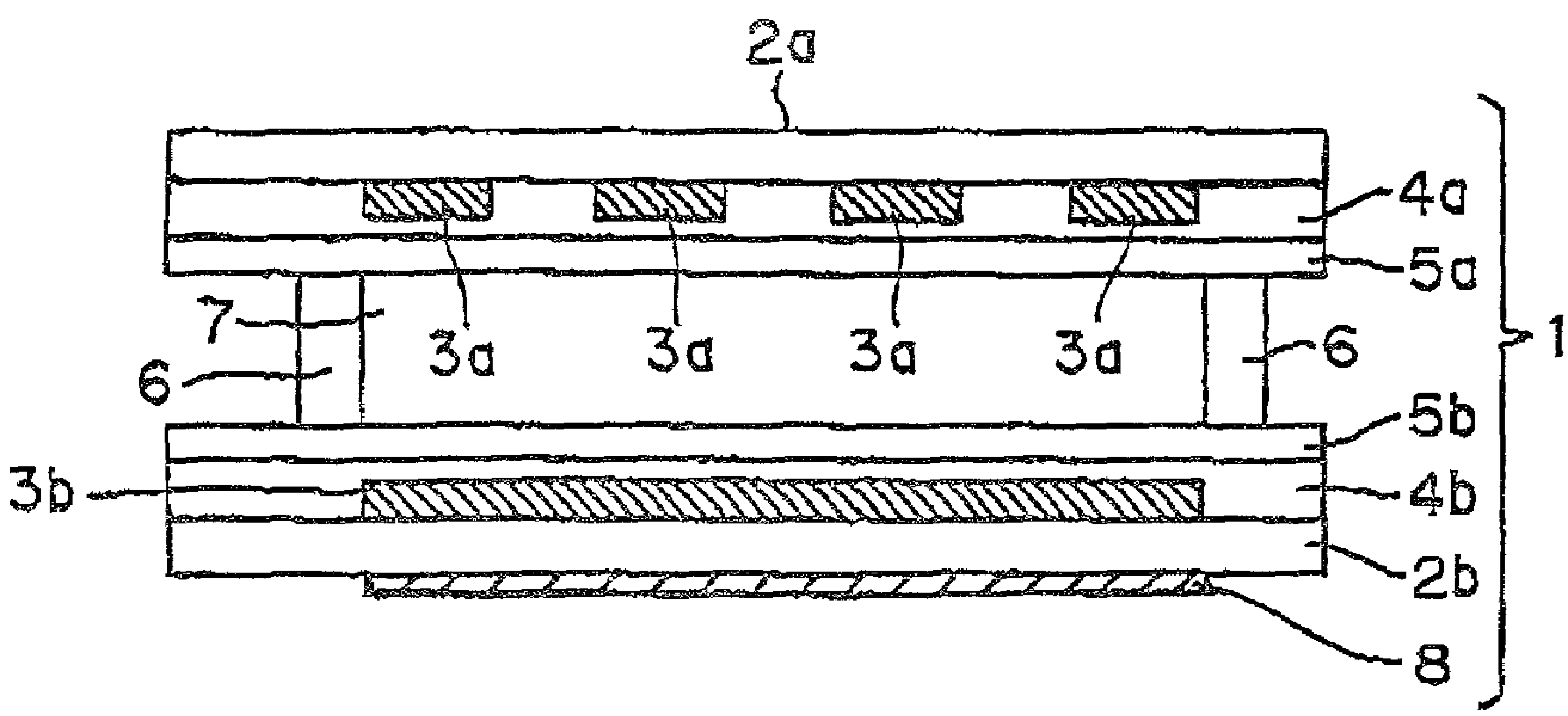
(Continued)

Primary Examiner—Thoi V. Duong
(74) *Attorney, Agent, or Firm*—Oblon, Spivak, McClelland, Maier & Neustadt, P.C.

(57) **ABSTRACT**

On substrates **2***a*, **2***b* of a chiral nematic liquid crystal optical element **1**, transparent electrodes **3***a*, **3***b* and electrical insulation layers **4***a*, **4***b* are formed, and further, resin layers **5***a*, **5***b* hating a pencil hardness of "B" or less are formed on the electrical insulation layers by a spin coating method so as to be in contact with a liquid crystal layer **7**. When the surface hardness of the resin layers is to be measured, a glass substrate on which a resin layer is formed by screen-printing is prepared as a test piece, and the test piece is fitted to a pencil-scratching tester. The surface hardness is measured by scratching the test piece with two kinds of testing pencil selected from testing pencils having 17 grades of density.

21 Claims, 8 Drawing Sheets



U.S. PATENT DOCUMENTS

5,235,445	A	8/1993	Hirai et al.	
5,453,863	A *	9/1995	West et al.	359/91
5,674,576	A *	10/1997	Gotoh et al.	428/1.2
5,856,853	A *	1/1999	Konuma et al.	349/42
5,936,691	A *	8/1999	Kumar et al.	349/124
6,072,558	A *	6/2000	Tanaka et al.	349/179
6,177,973	B1 *	1/2001	Lee et al.	349/123
6,233,027	B1 *	5/2001	Unno et al.	349/25
6,366,330	B1	4/2002	Khan et al.	
6,377,321	B1 *	4/2002	Khan et al.	349/35
2002/0057408	A1 *	5/2002	Nishiyama et al.	

FOREIGN PATENT DOCUMENTS

JP	62-123425	6/1987
JP	03-107925	5/1991
JP	05-196925	8/1993
JP	07-104297	4/1995
JP	08-114803	5/1996
JP	08-220326	* 8/1996
JP	A-10-31205	2/1998
JP	11-167126	6/1999
JP	11-288008	10/1999
JP	2000-267070	9/2000

OTHER PUBLICATIONS

Patent Abstracts of Japan; 2000267070; Sep. 29, 2000.
Patent Abstracts of Japan; 06003634; Jan. 14, 1994.
Patent Abstracts of Japan; 11002821; Jan. 6, 1999.
Patent Abstracts of Japan; 06118403; Apr. 28, 1994.
Patent Abstracts of Japan; 2000162441; Jun. 16, 2000.

* cited by examiner

Fig. 1

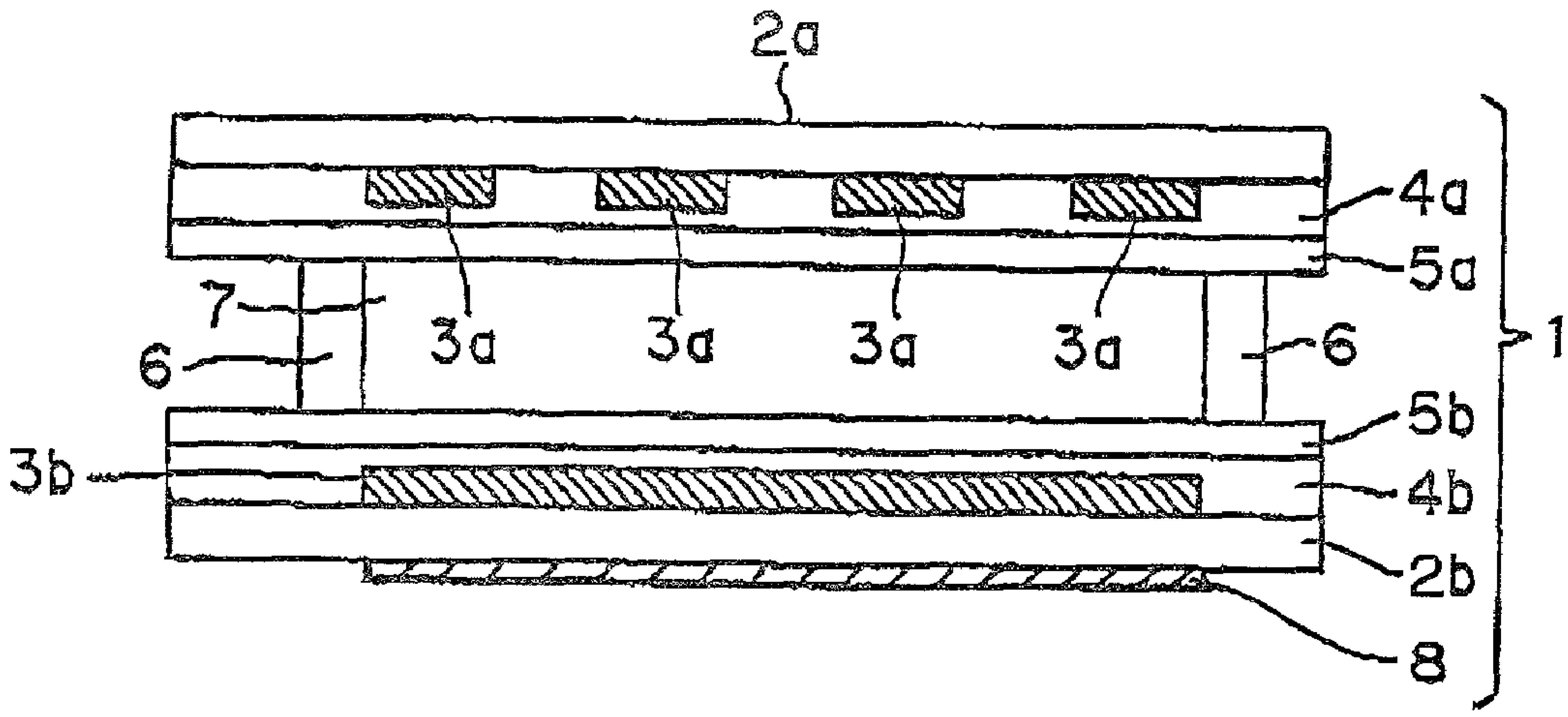

2a
4a
5a
7
3a
3a
3a
3a
6
6
1
5b
3b
4b
2b
8

Fig. 2

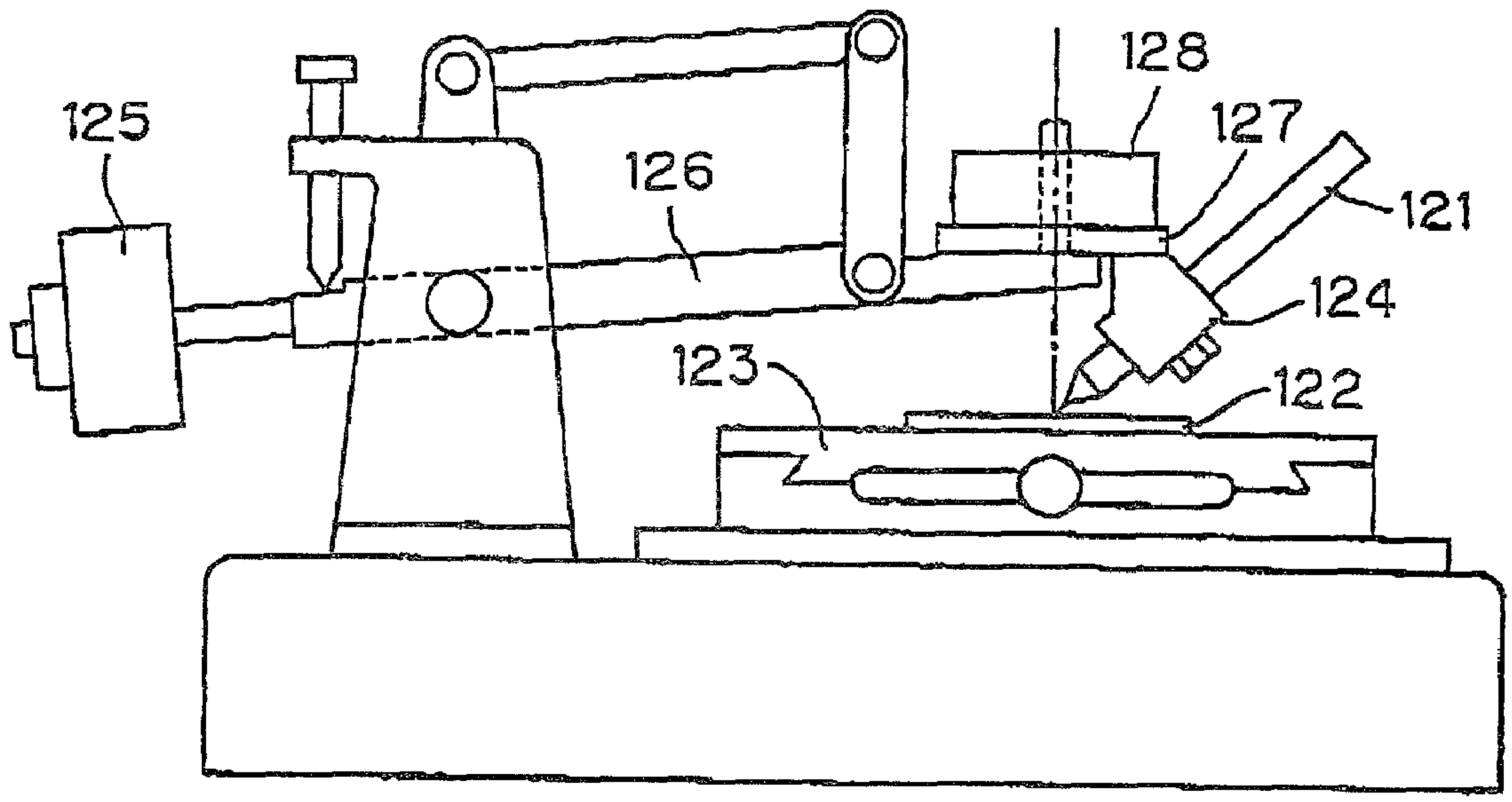

128
127
125
126
121
124
123
122

Fig. 3

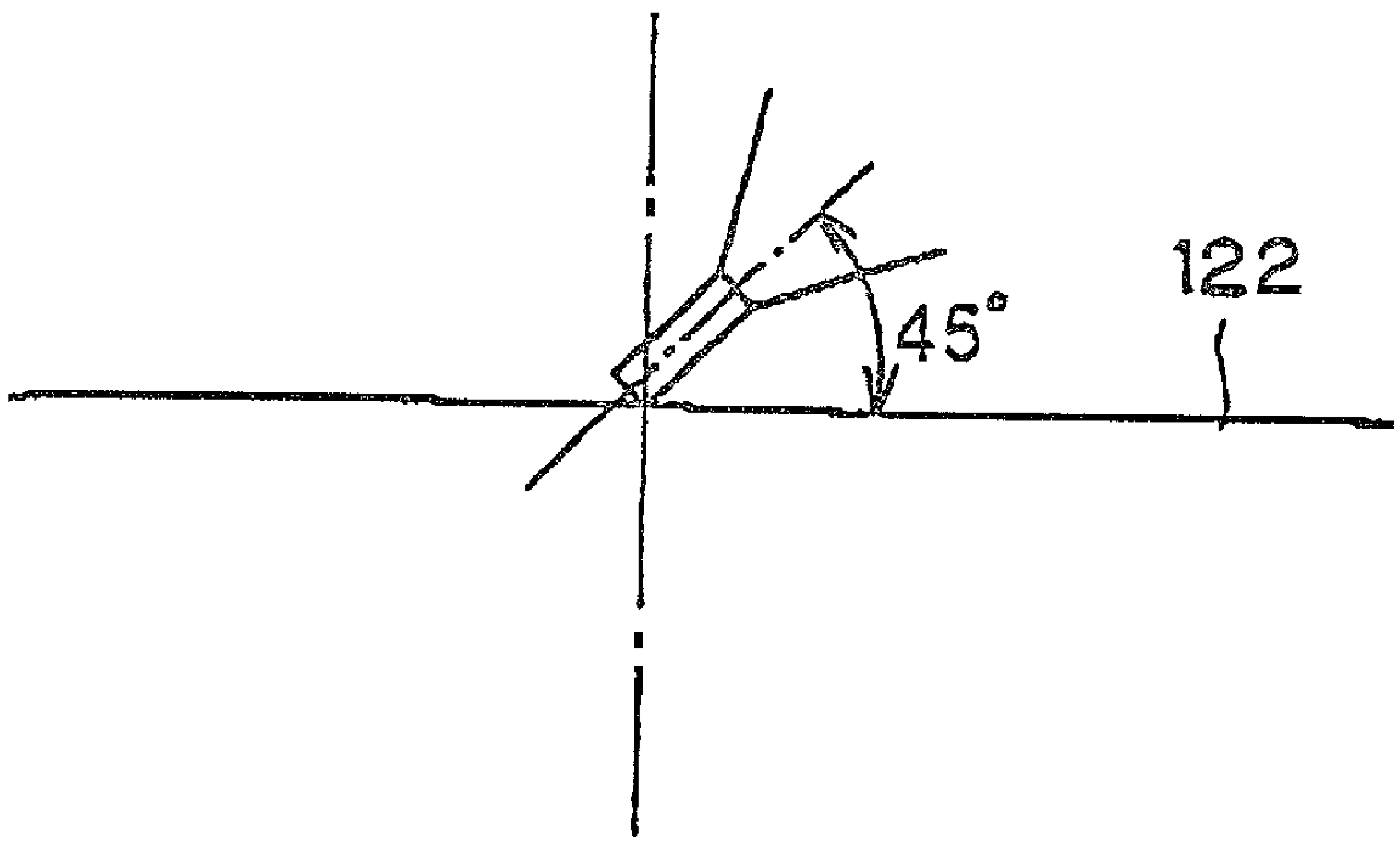


Fig. 4 (a)

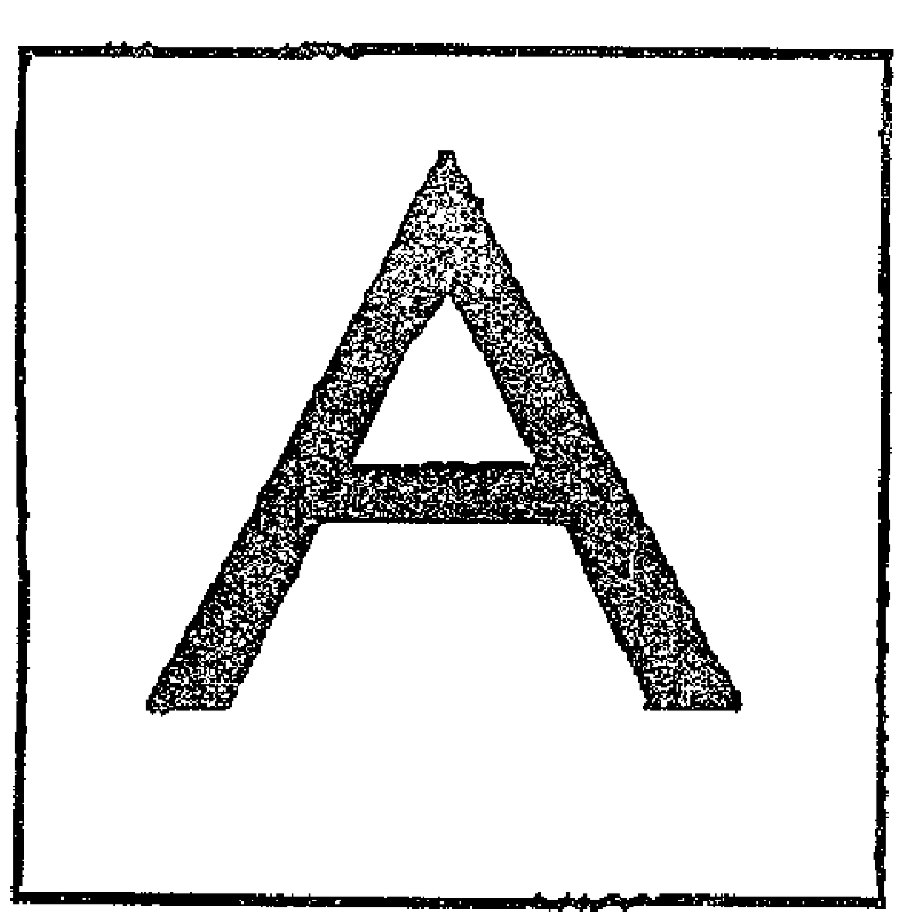


Fig. 4 (b)

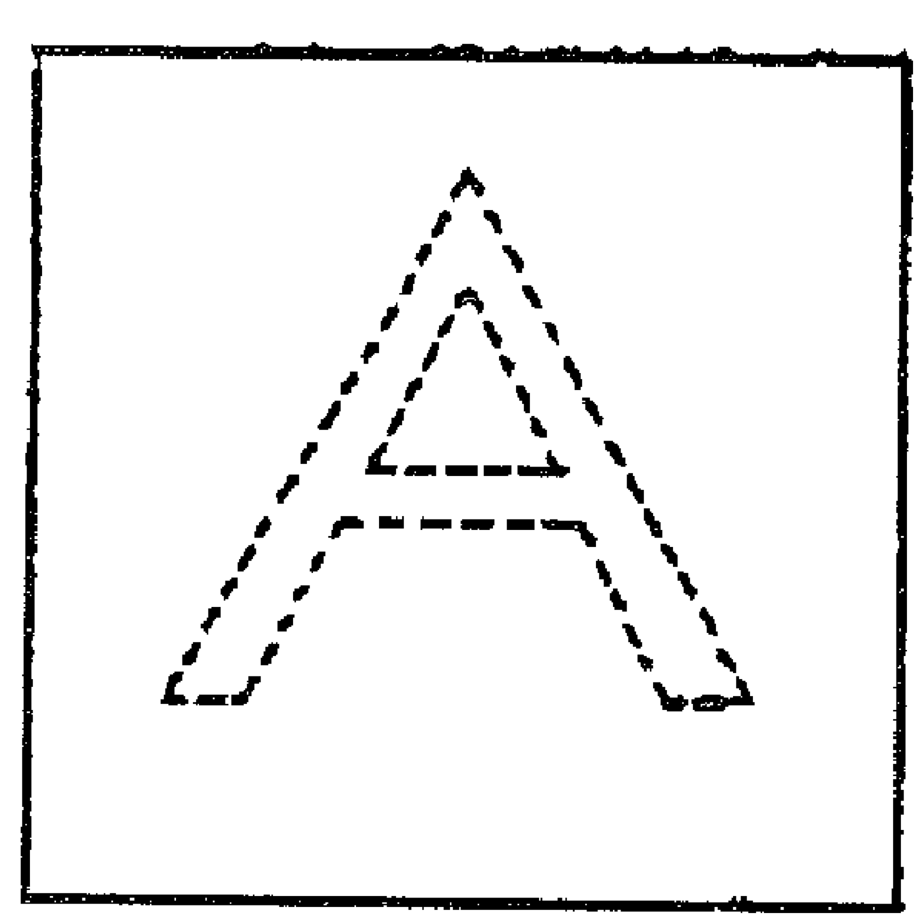


Fig. 5 (a)

Fig. 5 (b)

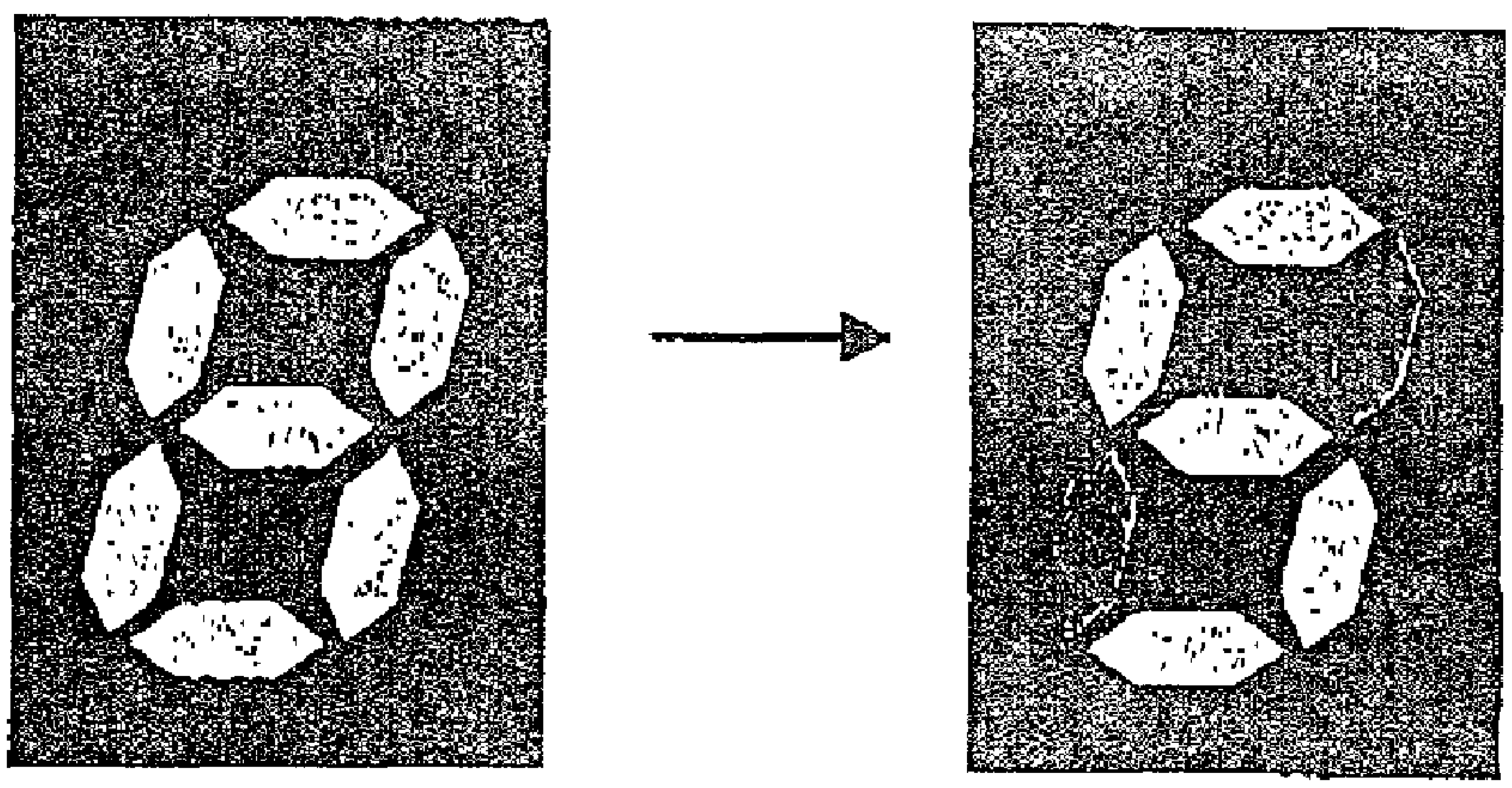


Fig. 6

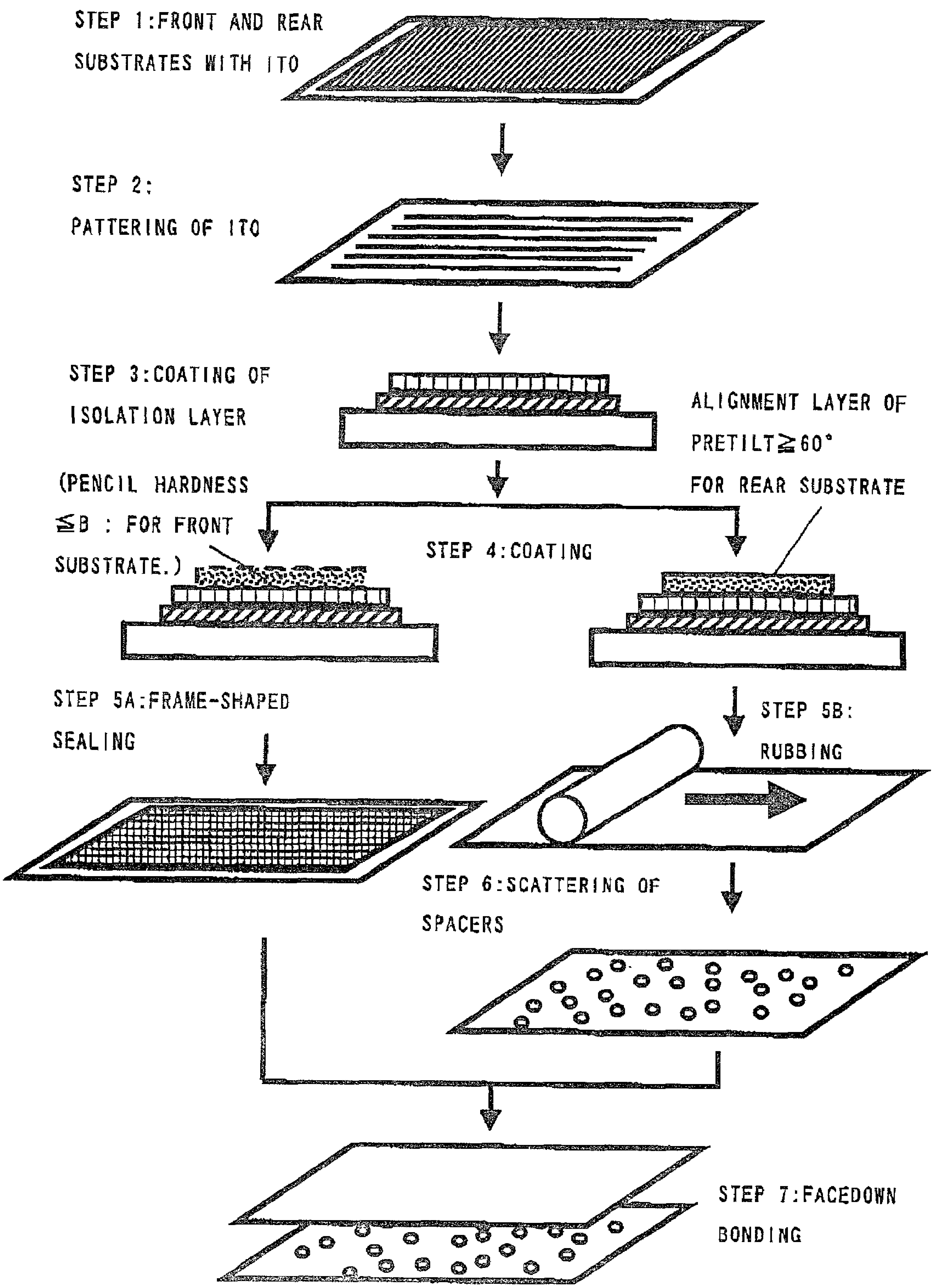

STEP 1:FRONT AND REAR
SUBSTRATES WITH ITO
STEP 2:
PATTERING OF ITO
STEP 3:COATING OF
ISOLATION LAYER
ALIGNMENT LAYER OF
PRETILT≧60°
FOR REAR SUBSTRATE
(PENCIL HARDNESS
≦B : FOR FRONT
SUBSTRATE.)
STEP 4:COATING
STEP 5A:FRAME-SHAPED
SEALING
STEP 5B:
RUBBING
STEP 6:SCATTERING OF
SPACERS
STEP 7:FACEDOWN
BONDING

Fig. 7 (a)

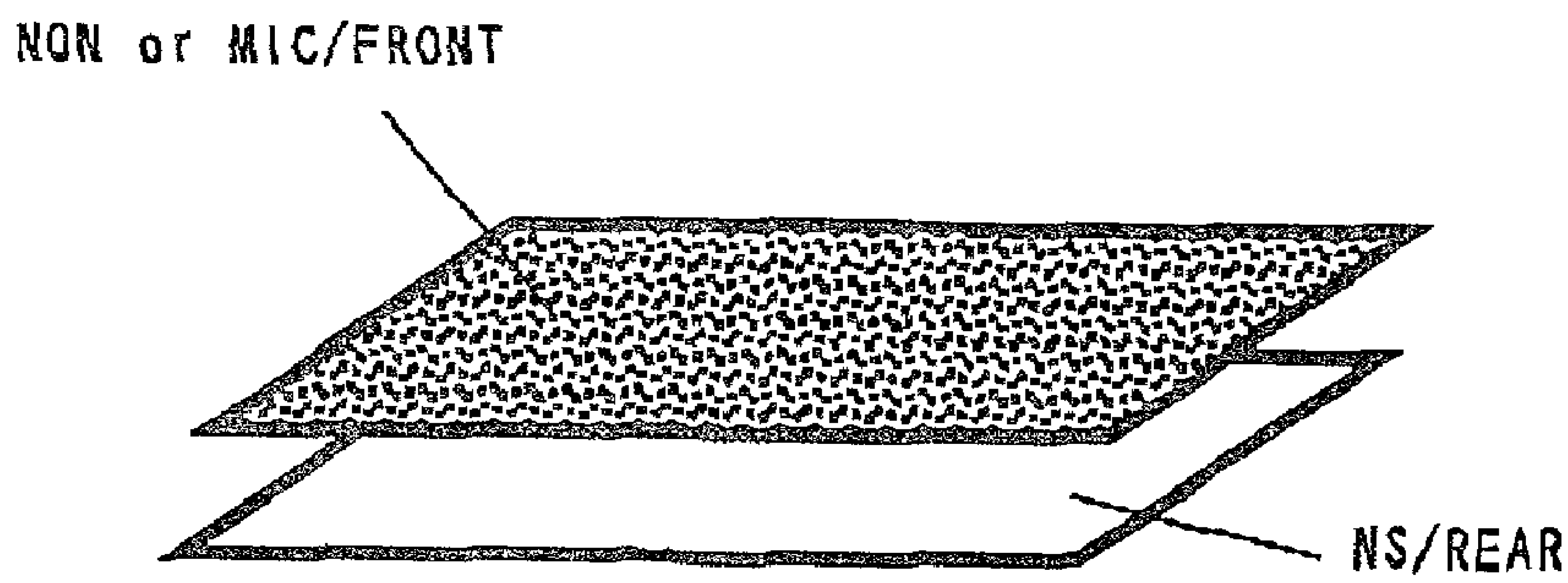


Fig. 7 (b)

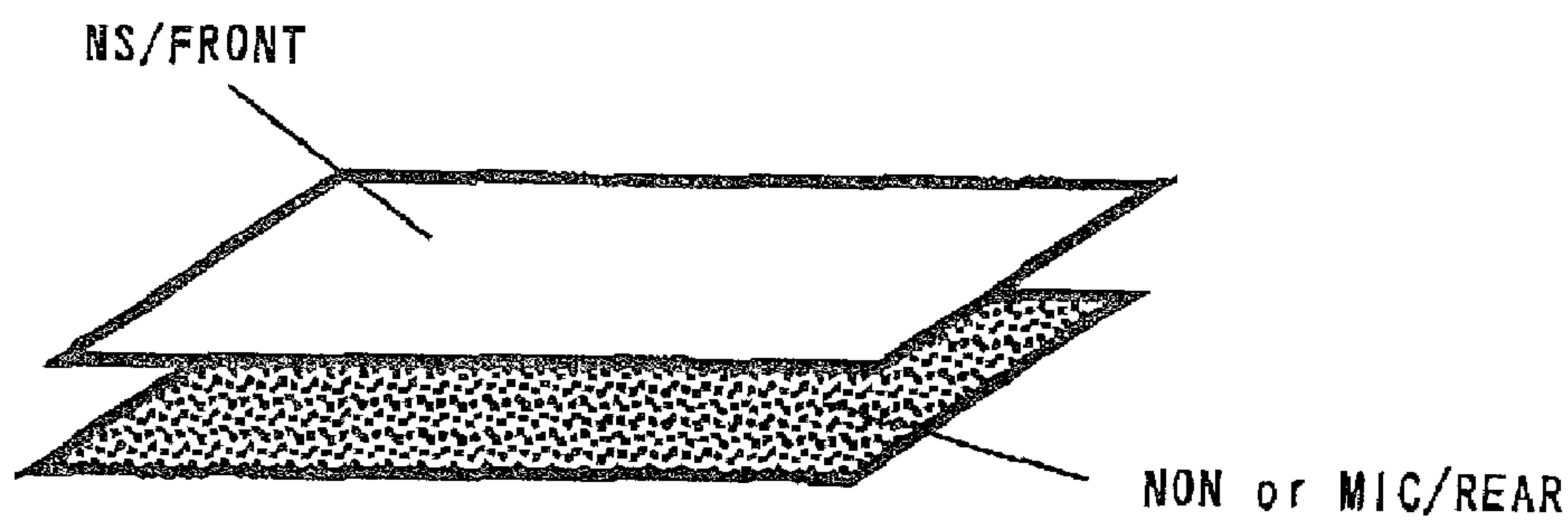


Fig. 7 (c)

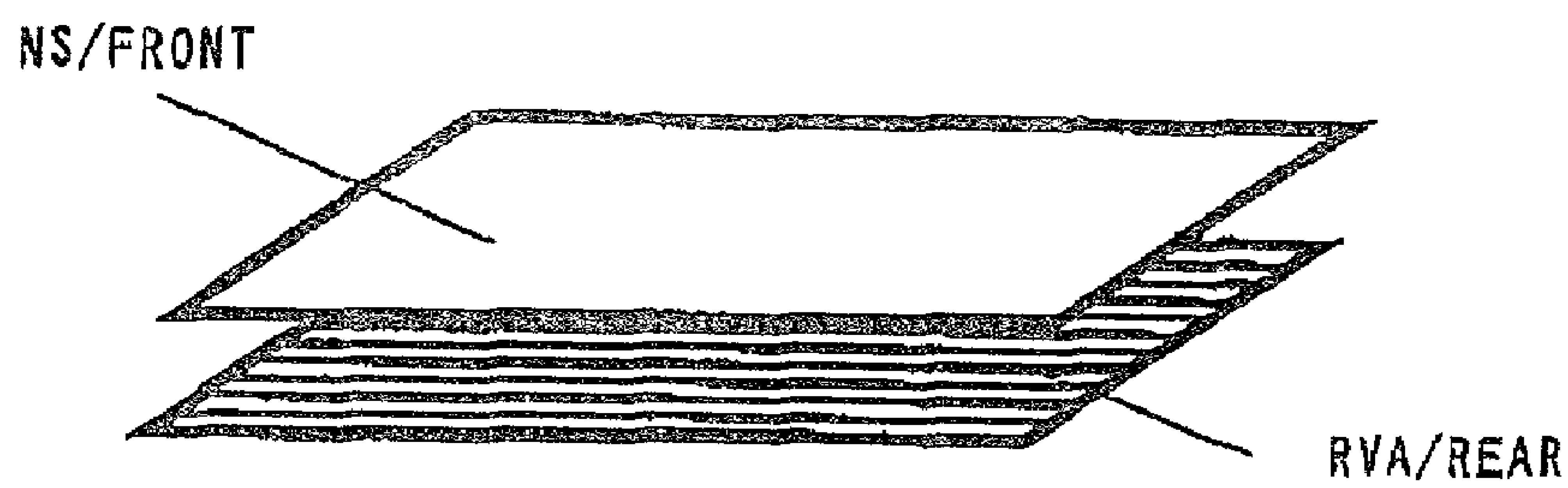


Fig. 7 (d)

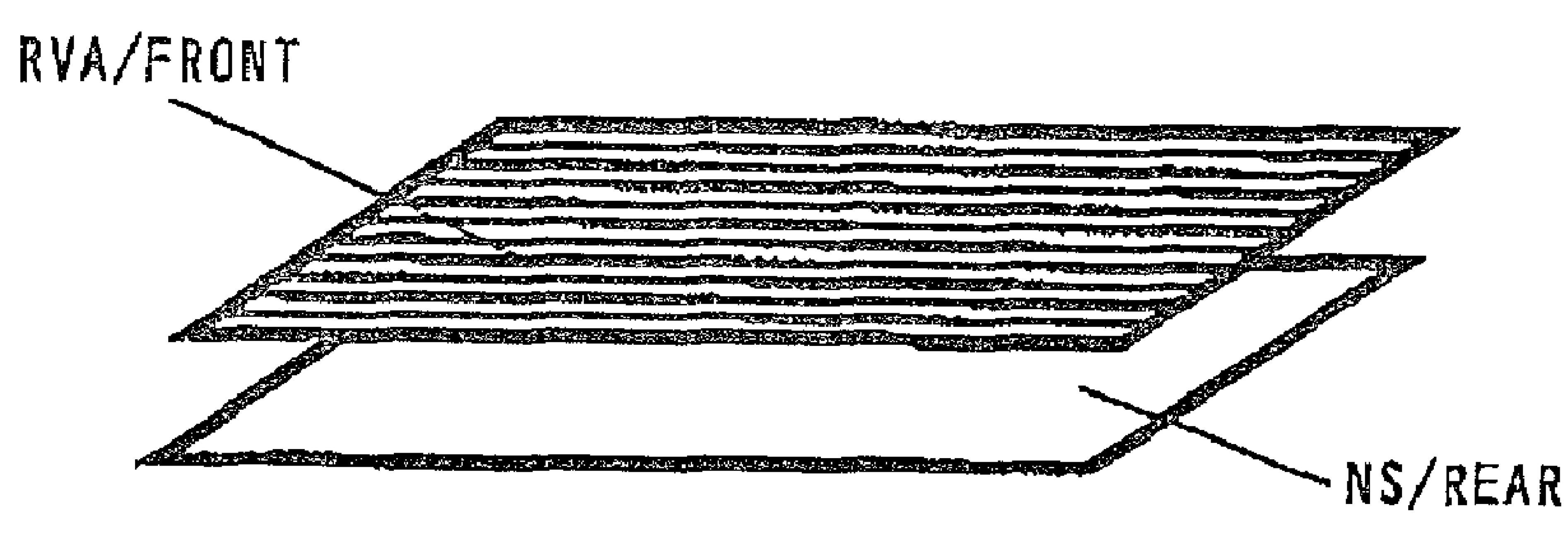


Fig. 8

MEAL MENU for the month of November, 2001

ARK-PLAZA KITCHEN

<Appetizer>

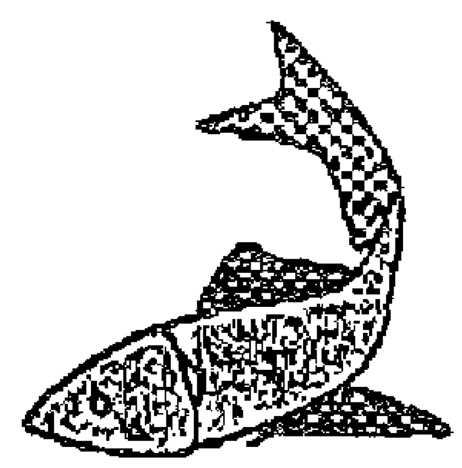
Shrimp Stuffed Dumpling........................$1.25

Fried Breaded Calamari........................ $1.50

<Soup>

Chiken cream soup..............$1.75

Spicy Korean soup..............$2.00



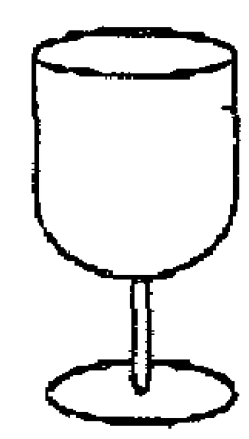
<Meat>

Tenderloin Steak.............. $25.00

Salmon Steak.................... $20.00

German Sausage..................$15.00

Mixed Grilled Plate...........$45.00



<Wine>

RED:Beaujolais – Vilages –

Barton & Guestier 1998(FR) $400.00

WHITE:Frascati –Ghiberti– 1999(IT) $380.00

Muscadet – Laboure Roi – 1995(FR) $520.00

<Sushi:all items are $1.00>

Uni(seaurchin),Ebi(shrimp),ikura(salmon eggs), ika(squid),tamago(egg),maguro(tuna) and many other Sushi-Dinner

<Side Order>

French Fries $2.00

Fried Shrimp $4.00

TODAY's special Menu: Beef/Cheese Piza...$15.25

Fig. 9

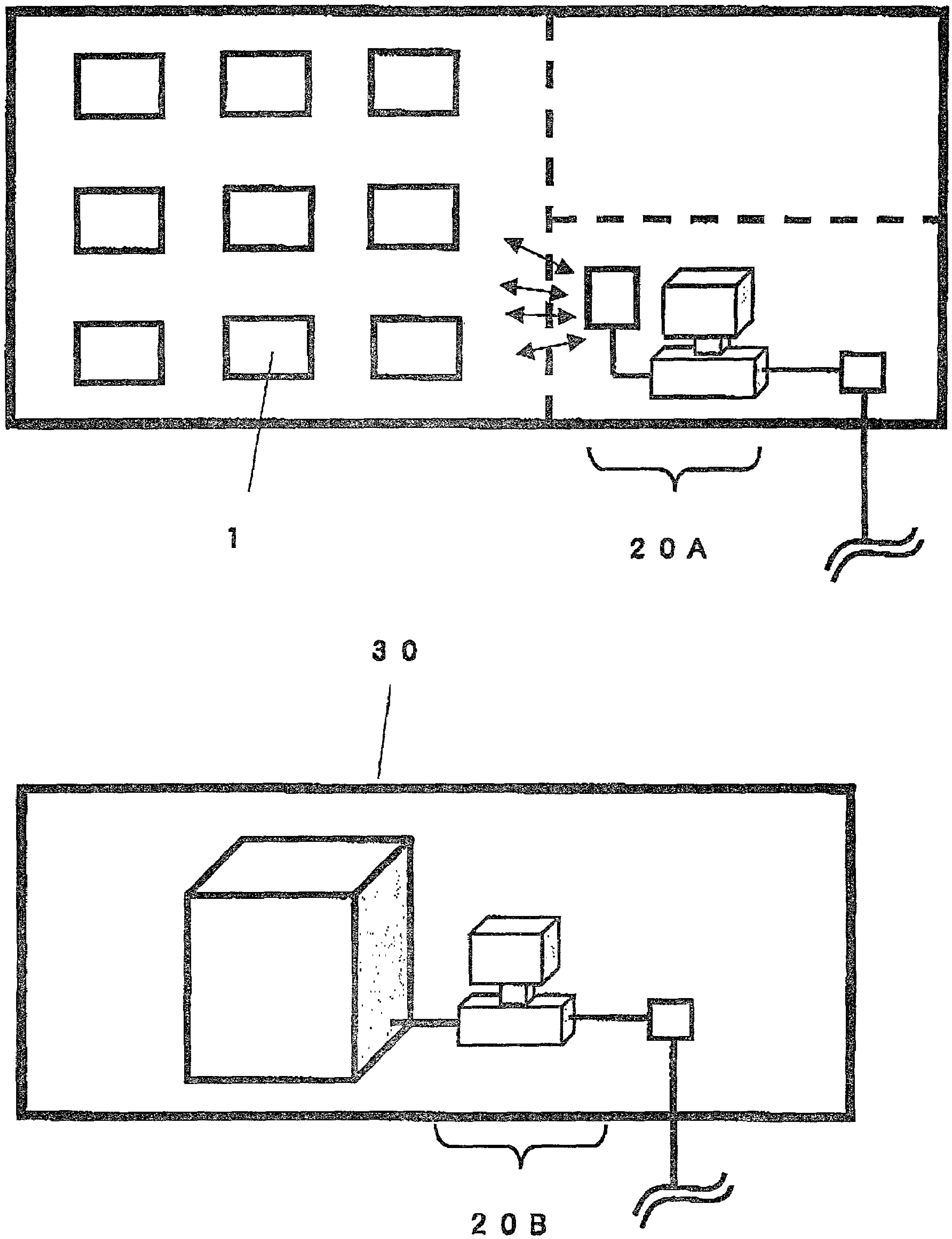
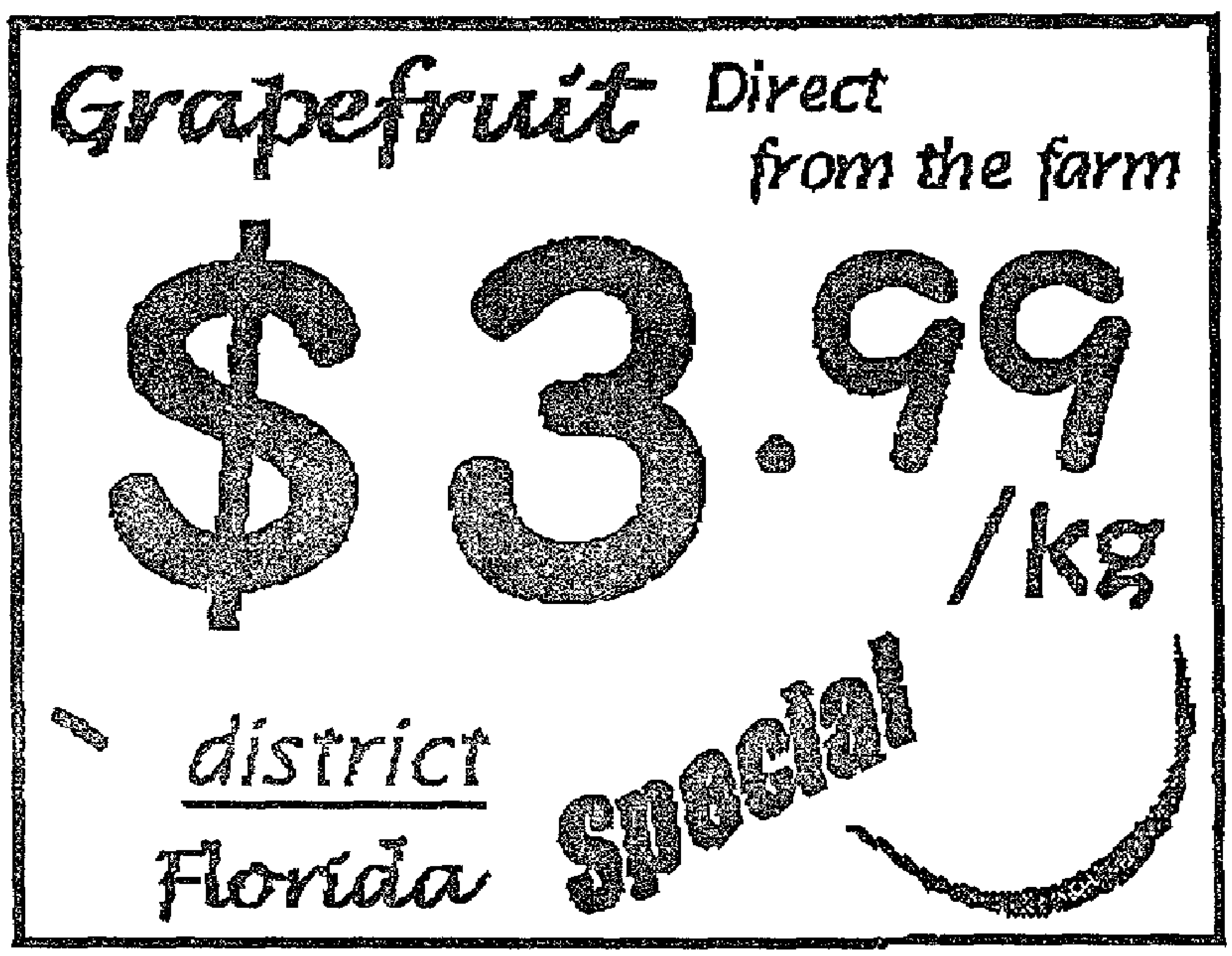


Fig. 10


Grapefruit
Direct
from the farm
$3.99
/kg
district
Florida
Special

LIQUID CRYSTAL OPTICAL ELEMENT COMPRISING A RESIN LAYER HAVING A SURFACE HARDNESS OF B OR LESS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. application Ser. No. 09/847,333, filed May 3, 2001 now U.S. Pat. No. 6,674,494. The present application claims priorities under 35 U.S.P. § 119 to Japanese Patent Application No. 2001-303,956, filed Sep. 28, 2001, and Japanese Patent Application No. 2001-308,018, filed Oct. 3, 2001. The specifications, the claims, the drawings and the summaries of these applications are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a liquid crystal optical element provided with a liquid crystal which exhibits two or more optically stable states in a non-voltage-application time.

2. Description of the Background

A chiral nematic liquid crystal optical element (hereinbelow, referred to as CL-LCD) has a phase-change type mode. It provides selective reflection in a planar state (hereinbelow, referred to as PL), and provides a scattering state in a focalconic state (hereinbelow, referred to as FC). By applying a predetermined voltage across the electrodes, the liquid crystal can be transformed into PL or FC. For example, when it is transformed from FC to PL, the liquid crystal is once rendered to be a homeotropic state (a state that liquid crystal molecules are aligned vertically to the substrate plane, and hereinbelow, referred to as HO), and then, it is transformed into PL. Then, the liquid crystal is stable in PL or FC even in a non-voltage-application time, and either state can be maintained.

Description will be made as to an optical display state. In FC, a slightly scattering state of incident light is produced, and in PL, a selective reflection of incident light is produced. Further, by adjusting the helical pitch (λ_{AVG}) of the liquid crystal layer, an operation mode of "transmittance-scattering" or a color display utilizing colors of selectively reflected light can be effected.

OPTREX Corporation as the assignee of the application has tentative U.S. Ser. No.: 09/813988 (patent application No., filed on Mar. 22, 2001) regarding electrodes for CL-LCD, and a display state of it and so on; U.S. Ser. No. 09/822,344 (filed on Apr. 2, 2001) regarding the relation of a driving method and a display state thereof and so on, and U.S. Ser. No. 09/824,102 (filed on Apr. 3, 2001) regarding a liquid crystal material and a chiral agent. The present application refers to and includes portions in common with and relating to these applications.

Next, description will be made as to a unique problem of CL-LCD originated from a memory state. A first problem is an "image-sticking phenomenon". This phenomenon is caused under the following conditions, for example. The state of CL-LCD is made to be a memory state in FC or PL, and it is left for a predetermined time in a non-voltage-application state. Then, even when a voltage corresponding to a new image is applied so as to change the display, the previous image remains.

In the following, such image-sticking phenomenon will be explained by taking a dot matrix type CL-LCD having

160 row electrodes and 160 column electrodes as an example. In this case, it is assumed that "an alignment layer" in contact with the liquid crystal layer at an inner side of the substrates is made of the same material as the one used for a TN or STN liquid crystal display element. Generally, since a surface of an aligning layer in the TN or STN liquid crystal display element is subjected to an aligning treatment by rubbing, a material having a high surface hardness (for example, 3H-6H in a pencil hardness test method) is used. In CL-LCD too for example, the same technique is used. As a concrete example on an aligning layer in contact with the liquid crystal layer, there is known a case of providing polyimide or a case without using any aligning layer (U.S. Pat. No. 5,453,863).

Then, a background portion of a display area of dot matrix type is made to be FC, and portions corresponding to characters, figures and so on are made to be PL. An example of displaying a character of "A" is shown in FIG. **4**(*a*). After such predetermined image has been provided, the application of a voltage is stopped, and the display panel is left for a long time in an incubator of 60° C.

Then, a voltage which makes the liquid crystal in the whole display area to be HO is applied. When the liquid crystal in the whole area becomes HO, the display in the whole area is extinguished. When a voltage is applied subsequently so that the liquid crystal in the whole area becomes FC, the whole area does not provide a uniform color but the character of "A" which has been previously displayed remains slightly as shown in FIG. **4**(*b*). Further, even in a case that the liquid crystal of the whole area is made to be PL via HO after the panel has been left for a long time, the display of "A" remains.

On the contrary, the image-sticking phenomenon takes place even in the following case. Namely, the liquid crystal in the background portion is made to be PL, and the liquid crystal in the portions corresponding to characters and so on is made to be FC. The display panel in such states is left for a long time, and then, a display in the whole area is extinguished by applying a voltage by which the state of the liquid crystal in the whole area of display becomes HO (the liquid crystal itself is in a transparent state). Subsequently, the whole display area is changed to PL or FC. In particular, the image-sticking phenomenon is apt to be observed in a case that a display state wherein the liquid crystal corresponding to the background portion is FC and the liquid crystal corresponding to characters and so on is PL is left for a long time, and then, the liquid crystal in the whole display area is made to be FC.

Further, image-sticking takes place as well in a case of CL-LCD having segment type electrodes. For instance, the image-sticking occurs when a display state wherein a display portion is PL and a background portion is FC is maintained for a long time, and then, such display is changed to another display.

In FIG. **5**(*a*), all 7 segments are ON to display a character of "8". A color display in combination of black in a background portion in FC and a selective reflection in a visible range in a segment portion in PL, is provided. In FIG. **5**(*b*), when a character of "5" is newly displayed, upper right and lower left segment portions are lit weakly.

However, when a display is performed in combination of PL and FC in CL-LCD, a PL portion is generally light and the highest visibility is obtainable. Accordingly, in a case of the segment type display in FIG. **5**, a possibility of causing erroneous recognition is relatively lower than the case of the dot matrix type in FIG. **4**.

The image-sticking phenomenon remains slightly even after a voltage for providing HO has continuously been applied and a state that the entire display area is erased has been continued for several hours. Further, in some cases, a display state having the image-sticking phenomenon (hereinbelow, also referred to as image-sticking) cannot be completely erased even after an isotropic state which is caused by heating the liquid crystal has been continued for several hours.

Accordingly, it is an object of the present invention to provide CL-LCD capable of preventing the occurrence of image-sticking even though the liquid crystal is left for a long time while the state of the liquid crystal is constant.

Next, a second problem is the brightness in display of CL-LCD. CL-LCD provides brighter display than TN-LCD or STN-LCD since CL-LCD can be basically used without using a polarizing plate. However, without carrying out alignment control, it is difficult to obtain sufficient brightness that is supposed to be exhibited. From this viewpoint, CL-LCD basically provides insufficient brightness in the "display" to be provided for a user in some cases.

This is because the brightness in the display is directly affected by the dispersion in the direction of helical axes in the entire liquid crystal layer in CL-LCD. Generally speaking, wider dispersions make a viewing angle wider and the display darker. Conversely, narrower dispersions make the viewing angle smaller and the display brighter. In principle, there is a contradiction between the size in the viewing angle and the brightness in the display in CL-LCD.

It is another object of the present invention to ensure a certain view and a certain degree of viewing angle but also attain bright display simultaneously in addition to prevention against the "image-sticking" stated earlier.

The inventors have conducted further research and development on the structure in a cell of CL-LCD and have found that CL-LCD capable of obtaining remarkably bright display having a high contrast ratio can be provided by collecting light in an observing direction by a user with a certain degree of viewing angle ensured.

Further, the present invention is to provide a liquid crystal optical element having excellent function without changing largely the conventional manufacturing method, and a test method for the liquid crystal optical element.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided a liquid crystal optical element comprising a pair of substrates with electrodes between which a liquid crystal layer including a chiral nematic liquid crystal is interposed wherein at least one of the substrates is transparent and the liquid crystal layer exhibits two or more optically stable states in a non-voltage-application time, the liquid crystal optical element being characterized in that a boundary layer is provided between an electrode on at least one of the substrates and the liquid crystal layer, and the surface hardness of the boundary layer is B or less in terms of a pencil hardness test.

In a second aspect, the above-mentioned liquid crystal optical element wherein the boundary layer is a resin layer is provided. In a third aspect, the above-mentioned liquid crystal optical element wherein the resin layer is of polyimide is provided. In a fourth aspect, the above-mentioned liquid crystal optical element wherein the electrode on at least one of the substrates is divided into a plurality of portions is provided. In a fifth aspect, the above-mentioned liquid crystal optical element wherein the surface hardness is 3B or less is provided. In a sixth aspect, the above-mentioned liquid crystal optical element wherein a dot matrix display is performed with the electrodes is provided. In a seventh aspect, the above-mentioned liquid crystal optical element wherein a segment display is performed with the electrodes is provided. In an eighth aspect, the above-mentioned liquid crystal optical element wherein the heat distortion temperature of a material for forming the boundary layer is 50° C. or more, and the Young's modulus at room temperature is 1 kPa or more, is provided.

According to a ninth aspect, the liquid crystal optical element in any one of the first to eight aspects, wherein a second resin layer having a pre-tilt angle of 60° or more is provided on the other electrode, the rubbed alignment surface of said second resin layer is arranged to be in contact with the liquid crystal layer.

According to a tenth aspect, the liquid crystal optical element in the ninth aspect, wherein the second resin layer is provided only on the substrate on a side opposite to an observing side, is provided.

According to an eleventh aspect, the liquid crystal optical element in any one of the first to eight aspects, wherein the other transparent electrode has an electrical insulation layer of metal-oxide provided thereon, and wherein the electrical insulation layer is provided in contact with the liquid crystal layer, is provided.

According to a twelfth aspect, the liquid crystal optical element in the eleventh aspect, wherein the paired transparent electrodes have a drive voltage of 20V or less applied thereacross, is provided.

Further, according to a thirteenth aspect, there is provided a test method for a liquid crystal optical element comprising a pair of substrates with electrodes between which a liquid crystal layer including a chiral nematic liquid crystal is interposed wherein at least one of the substrates is transparent and the liquid crystal layer exhibits two or more optically stable states in a non-voltage-application time, the test method being characterized in that a boundary layer is provided between an electrode on at least one of the substrates and the liquid crystal layer, and judgment is made as to the presence or absence of an image-sticking phenomenon after the liquid crystal optical element has been left for 1 hour or more in a state of maintaining a predetermined image.

Further, according to a fourteenth aspect, there is provided a test method for a boundary layer of a liquid crystal optical element comprising a pair of substrates with electrodes between which a liquid crystal layer including a chiral nematic liquid crystal is interposed wherein at least one of the substrates is transparent; the liquid crystal layer exhibits two or more optically stable states in a non-voltage-application time, and a boundary layer is provided at at least a part between an electrode on at least one of the substrates and the liquid crystal layer, the test method for a boundary layer of a liquid crystal optical element being characterized in that a test means having a predetermined ranking of hardness is provided; the test means is brought to contact with the boundary layer N times ($1 \leqq N$) or more while a pressure is applied to the test means, and evaluation is made as to the surface hardness of the boundary layer based on whether or not a flaw is resulted in the boundary layer, whereby applicability to the liquid crystal layer is determined.

Further, according to a fifteenth aspect, there is provided a liquid crystal optical element comprising a pair of substrates with transparent electrodes and a liquid crystal layer interposed between the substrates and having a memory property, wherein a first resin layer is provided on at least one of the transparent electrodes, a rubbed alignment surface of said first resin layer is arranged to be in contact with the liquid crystal layer.

Further, according to a sixteenth aspect, the liquid crystal optical element in the fifteenth aspect, wherein the first resin layer may be provided only on the substrate on a side opposite to an observing side.

The other electrode may have a second resin layer provided thereon, the second resin layer may be provided in contact with the liquid crystal layer, and the second resin layer may have a surface hardness of B or less in a pencil hardness test in these liquid crystal optical elements.

There is also provided a liquid crystal optical element comprising a pair of substrates with transparent electrodes and a liquid crystal layer interposed between the substrates and having a memory property, wherein at least one of the transparent electrodes has a metal-oxide layer provided thereon, and the metal-oxide layer is provided in contact with the liquid crystal layer.

The paired transparent electrodes may have a driving voltage of 20V or less applied thereacross in this liquid crystal optical element.

The other electrode may have a second resin layer provided thereon, the second resin layer may be provided in contact with the liquid crystal layer, and the second resin layer may have a surface hardness of B or less in terms of a pencil hardness test in these liquid crystal optical elements.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatical cross-sectional view showing an embodiment of CL-LCD according to the present invention;

FIG. **2** is a diagram showing a pencil-scratching tester;

FIG. **3** is an explanatory diagram showing a pencil in contact with a test piece;

FIG. **4**(*a*) is an explanatory diagram showing a correct display of a character of "A", and FIG. **4**(*b*) is an explanatory diagram showing a state of image-sticking;

FIG. **5**(*a*) is a diagram showing a correct display of a character of "8" in a segment type CL-LCD, and FIG. **5**(*b*) is a diagram showing a state of image-sticking phenomenon;

FIG. **6** is a flow chart showing a method for preparing a liquid crystal optical element according to the present invention;

FIG. **7** is a schematic perspective view of a liquid crystal optical element according to the present invention;

FIG. **8** is an explanatory diagram showing how a menu display unit with a liquid crystal optical element according to the present invention applied thereto performs display;

FIG. **9** is an explanatory diagram showing how a menu display unit with a liquid crystal optical element according to the present invention applied thereto is used at a restaurant; and

FIG. **10** is an explanatory diagram showing how a price display unit or an electronic shelf label system (ESL) with a liquid crystal optical element according to the present invention applied thereto performs display.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is considered that the image-sticking phenomenon takes place by such effect that the orientation of liquid crystal molecules in a state that the previous phase state is preserved (hereinbelow, referred to as a preservation state) without applying no voltage to the liquid crystal layer, is fixed from a side of the interface. The interface is a region between a boundary layer provided on an electrode and the liquid crystal layer. It is considered that the image-sticking phenomenon takes place by that a state of the liquid crystal molecules at the interface is influenced with a lapse of time in a preservation state.

In the preservation state, there is a case that the orientation of liquid crystal in an inner portion is changed so as to have a stable orientation because the orientation is fixed in a long time. When the surface hardness of the boundary layer to which the liquid crystal contacts is high (high hardness), the orientation of the liquid crystal molecules at the interface changes inelastically. When the preservation state is canceled and the orientation of the liquid crystal is changed to have a different state, a history remains in the orientation of the liquid crystal at the interface. Accordingly, the orientation of the liquid crystal in the preservation state may influence liquid crystal in the vicinity of the interface.

On the contrary, in the boundary layer in contact with the liquid crystal layer, when the heat distortion temperature is less than 50° C.; the Young's modulus at room temperature is less than 1 kPa and the boundary layer is very soft and has a high fluidity, the boundary layer may be deformed with a change in a state of the orientation of the liquid crystal layer at a high temperature. Then, there causes a problem that the boundary layer does not return to the original state, and the display changes.

Therefore, it is preferable that the material to form said boundary layer has the heat distortion temperature which is 50° C. or more, and has the Young's modulus at room temperature which is 1 kPa or more. Further, it is preferable that the heat distortion temperature is 80° C. or more, and the Young's modulus at room temperature is 100 kPa or more.

On the other hand, when the boundary layer in contact with the liquid crystal layer has a low hardness and is relatively soft, liquid crystal molecules in the vicinity of the interface can behave elastically. Namely, even though the orientation of the liquid crystal in the vicinity of the interface is able to be changed by suffering influence from the orientation of the liquid crystal in an inner portion to have a stable alignment in the preservation state, the liquid crystal in the vicinity of the interface can return to the original state of orientation, as if an elastic deformation is restored, by applying a voltage to change the orientation of the liquid crystal in an inner portion. Accordingly, there is no possibility that the orientation of the liquid crystal in the vicinity of the interface in the preservation state is fixed.

In other words, when the liquid crystal molecules are controlled by applying a voltage from an outer side, and a display is performed by utilizing a memory state by canceling the voltage, it is preferable that the liquid crystal in an inner portion of the bulk of the liquid crystal layer and in the region of the interface can behave in substantially same manner. It is preferable that physical properties of the boundary layer are determined in consideration of the liquid crystal used.

For this purpose, a material having a low Young's modulus and being relatively soft is used for the boundary layer in contact with the liquid crystal, whereby image-sticking in CL-LCD can be prevented. Further, as such boundary layer, a resin layer having a surface hardness of "B" or less in a pencil hardness test method is used. As a polymer material used for the boundary layer, a material having durability to liquid crystal, temperature stability, easiness in manufacturing and a surface hardness having a predetermined softness may be used. It is preferable that an aligning treatment by rubbing is not used to the surface of the resin layer. The following test method can be employed to measure the surface hardness.

Test tools of Q kinds of hardness ranking each having different hardness are prepared. Two or more test tools which are consecutive in hardness ranking are selected. They are brought to contact with the boundary layer in contact with the liquid crystal layer N times ($1 \leqq N$) or more respectively while a pressure is applied, and a difference of flaws resulted in the boundary layer is observed. When a significant difference is observed, surface hardness is determined. When the number of times of the occurrence of flaws per N times is K times ($1 \leqq K \leqq N$), the boundary layer satisfying the following conditions is found. Further, the test method may be simplified, and a predetermined standard is previously determined. Namely, judgment of 0/1 can be conducted in the detection of once time. This method can be applied to a sampling inspection in a production process.

In the case of N=1 or 2,
(1) K=0 on the M th test tool and
(2) $1 \leqq K$ on the M+1 th test tool
In the case of N=3 or more,
(3) K/N<0.4 on the M th test tool and
(4) $0.4 \leqq K/N$ on the M+1 th test tool.

In the following, CL-LCD of the present invention will be described with reference to the drawings. FIG. **1** shows a cross-sectional view of an embodiment of CL-LCD. A first substrate **2***a* is arranged at a front side and a second substrate **2***b* is arranged at a rear side wherein at least a part of the substrate **2***a* is transparent. The substrate **2***b* may be opaque. Glass or plastics may be used for the substrates. A black coating or a colored layer which absorbs or reflects partly visible light is arranged as a light absorbing layer **8** on an outer surface of the substrate **2***b* at a rear side. Further, a color filter may be provided at an inner surface side of the substrate to adjust visibility and so on.

In the following, a case that the substrates **2***a*, **2***b* are both transparent will be described. A transparent electrode group **3***a* is arranged at a front side and a transparent electrode group **3***b* is arranged at a rear side so as to cross perpendicularly. Either is determined to be a row electrode group; the other is to be a column electrode group, and each crossing portion of the row electrode group and the column electrode group is to be each pixel. The light absorbing layer **8** is provided at the rear surface side so as to correspond to a display portion. Further, an electrical insulation layer **4***a* is formed on the transparent electrode group **3***a*, and a resin layer **5***a* which is not subjected to an alignment treatment by rubbing is formed on the electrical insulation layer **4***a*. The surface hardness of the resin layer **5***a* is determined to be "B" or less in a test value according to a pencil hardness test which will be described later.

For example, the resin layer **5***a* may be formed by using a polyimide resin. In this case, it is preferable that a state of the baked surface is used as it is. The resin layer may be formed on either one of the substrates **2***a*, **2***b*. However, it is preferable to form the resin layer **5***b* at a rear surface side in the same manner as at a display surface side.

The substrates **2***a*, **2***b* are pressed by interposing a peripheral sealing material **6** to form a cell gap into which a chiral nematic liquid crystal layer **7** is introduced. The liquid crystal is driven by a voltage applied across the electrodes so that transition in a phase state is controlled.

Next, a test method for the boundary layer according to the present invention will be described. First, a test piece was prepared to test the surface hardness, and tests were conducted with testing pencils and a pencil-scratching tester. The test method is based on in principle JIS K 5400 8.4 (Japanese Industrial Standard defining the surface properties of coating or the like. There is ASTM D-3363 in U.S.A. and Europe as a similar test method/standard). The method for forming a coating on the test piece and the length on the test piece scratched with pencils were according to different procedures from JIS K 5400. The procedures are described specifically.

On a glass substrate having a size of 10 cm×10 cm and a thickness of 0.7 mm, a solution of resin was coated by screen printing. It was baked at 250° C. for 60 min to form a resin layer having a thickness of about 600 Å. As the test piece, such one that the resin layer was formed, and then, it was left one day or more, was used. The test piece forming procedures are different from those of JIS K 5400.

Testing pencils as described in JIS S 6006 are used. As the testing pencils, there are those in a set having a series of density signs proposed by Japan Paint Inspection and testing Association. In the hardness of pencils, a density sign of 9H is the hardest and 6B is the softest. A harder one has an upper ranking. In the measurement, the core of a testing pencil is exposed to about 3 mm in a circular column shape by using a cutting knife. Then, the core is put on a polishing paper perpendicularly, and it is polished so that the top end is flat and the angle is acute. As the polishing paper, the polishing paper of No. 400 described in JIS R 6252 is used.

As the test method, a scratching method by a human hand was not employed but a method by a tester was employed. As the tester, a surface characteristics measuring instrument of TYPE-HEIDON. 14 (hereinbelow, referred to as measuring instrument) manufactured by Shinto Kagakusha was used. FIG. **2** shows a state that a test piece and a pencil are attached to the measuring instrument. In measuring the hardness of a resin layer, a test piece **122** is attached to a test piece mounting table **123** of the measuring instrument. In this case, the test piece is fixed horizontally with an adhesive tape directing the coated surface upward.

The test piece **122** should be fixed to the test piece mounting table **123** so as not to move in a direction of the movement of the table. Subsequently, a testing pencil **121** is selected, and it is attached to a pencil holder **124** so that the top end of the core of the pencil is brought to contact with the coated surface (the resin layer). FIG. **3** shows a state that the core of the pencil having a flat top end and an acute edge is in contact with the coated surface at an angle of 45°.

Then, a balance weight **125** is adjusted so that the load of the pencil **121** applied to the test piece **122** is not deflected in a positive or negative side. The pencil **121** is separated from the coated surface; a lever **126** is fixed, and a weight **128** having 1.0 kg is placed on a weight table **127** so that the pencil **121** is again brought to contact with the coated surface, and the load of the weight **128** is applied to the top end of the core.

In this state, the pencil mounting table **123** is moved at a constant speed of 0.5 mm/s. In the measuring instrument, the test piece mounting table **123** is moved by driving a motor. By such movement, the coated surface of the test piece **122** is scratched in a length of about 10 mm with the core of the pencil **122**. Thus, a test of one time is finished. After the test of one time, the core of the pencil **121** is again polished, and the same test is conducted. 5 Times of test are conducted to one pencil.

The procedures of measurement was principally based on JIS K 5400 as described above provided that the length of scratching the test piece with the pencils was determined to be about 10 mm. Although the length of scratching is 3 mm in JIS K 5400, the length was determined to be long in order to obtain easy confirmation of the presence or absence of a flaw in the resin layer. Basically, the same effect is obtainable in the case of 3 mm.

After 5 times of test were conducted on the one pencil, a pencil having the next density sign was selected to conduct 5 times of test similarly. These tests are conducted successively on pencils of different density sign.

A pair of pencils whose density signs are adjacent to each other in which there is a pencil wherein a "drag mark" is recognized 2 times or more among 5 times of test, and a pencil wherein the drag mark is recognized less than 2 times, are selected. In the selected pair of pencils, the density sign on the pencil wherein the occurrence of the "drag mark" is less than 2 times is determined to be the surface hardness of the resin layer. Namely, a group of pencils of 17 grades: 6B, 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H and 9H, is prepared. Then, the density sign of a pencil having the hardness at a lower side, selected from this pencil group, wherein the occurrence of drag marks is less than 2 times among 5 times when a test piece is scratched each 5 times with two pencils having adjacent grades of density sign, is adopted. Accordingly, in the pencil having a higher hardness ranking by 1 grade, the occurrence of the drag mark is 2 times or more among 5 times.

Here, the "drag mark" means a flaw which slightly bites in the surface of the coated layer, and excludes a concave in the coated layer resulted from the application of a pressure. A distinguishable flaw under the following conditions is defined as "drag mark". Carbon powder is removed with an erasing rubber so as not to damage the coated layer in the tested portions, and visual observation is conducted from a direction perpendicular to the direction of scratching and from an angle of 45° to the test plane. As the erasing rubber, a plastic erasing rubber described in JIS S 6050 is used.

Now, explanation will be made about a method for attaining display in high brightness in CL-LCD. In a "normal PL state" of CL-LCD, there are slight dispersion in the direction of helical axes of respective domains formed in the liquid crystal layer. This results in dispersions in the direction and the strength of selective reflection. As the result, a user who observes selective reflection light from CL-LCD can perceive the reflection light in moderate brightness at a wide viewing angle.

In accordance with the present invention, the alignment layer of at least one of the substrates is a vertical alignment layer subjected to rubbing (hereinbelow, also referred to as RVA: Rubbed Vertical Alignment).

As a result, some of helical axes of the domains in a region of the liquid crystal in contact with the RVA are aligned by surface interaction, for example anchoring strength. Thus, coupling occurs between planar domains. There is a clear tendency for planar domains to be formed at a greater size than normal. As a result, the liquid crystal layer exhibits reflection characteristics as if the liquid crystal layer is a mirror. Thus, it becomes possible to perform display with light having high brightness.

On the other hand, when an interface obtainable by subjecting a horizontal alignment layer to a rubbing treatment is provided on one of the inner planes of the liquid crystal cell, the following situations are provided. When the liquid crystal layer is in PL, the liquid crystal layer performs display in high brightness as in the case stated earlier. When the liquid crystal layer is in FC, the alignment tends to partly returns to planar alignment. In the latter case, selective reflection by PL overlaps with scatter by FC. As a result, the contrast ratio reduces to about 50-60% in comparison with the contrast ratio in normal display with two states of PL and FC utilized therein.

Next, a method for manufacturing a liquid crystal optical element **1** will be described. First, two substrates with transparent conductive layers such as ITO (indium tin oxide) were prepared. To each substrate, an electrode group having predetermined interline spaces (spaces between electrodes) and a predetermined number of electrodes were formed by etching, and an electrical insulation layer was formed at a side of the transparent electrode forming surface of each of the substrates.

FIG. **1** schematically shows a liquid crystal optical element according to the present invention in section. The front substrate **2**_a_ has the transparent electrodes **3**_a_ provided thereon, and the rear substrate **2**_b_ has the transparent electrodes **3**_b_ provided thereon. The electrical insulation layer **4**_a_ and an electrical insulation layer **4**_b_ are formed, respectively, on the transparent electrodes on the front substrate and the transparent electrodes on the rear substrate for smoothness as an additional purpose. The resin layer **5**_a_ and a resin layer **5**_b_ are formed on the electrical insulation layers, respectively. FIG. **6** shows a flow in the method for preparing a liquid crystal optical element according to the present invention. FIG. **7** is a perspective view of a prepared liquid crystal optical element.

In the present invention, at least one of the resin layers **5**_a_, **5**_b_ is configured to have a pre-tilt angle of 60° or more (preferably 80° or more) and be subjected to a rubbing treatment. A color filter may be provided on an inner plane of one of the substrates for a purpose, such as adjustment in visivibility.

The alignment resin layer, which is subjected to rubbing and has a pre-tilt angle of 60° or more, may be provided only on the second substrate **2**_b_ on the rear side. In this case, extremely strong surface interaction, for example anchoring strength is produced in the vicinity of the interface of the liquid crystal layer.

Specifically, helical axes in the liquid crystal are induced to align in a direction perpendicular to the substrate plane to provide a high reflection state to incident light. On the other hand, the viewing angle becomes relatively wider in the vicinity of the interface between the first substrate **2**_a_ and the liquid crystal layer since there are some degree of dispersions in the direction of selective reflection because of dispersion in the directions of the helical axes in the liquid crystal due to lack of surface interaction, for example anchoring strength.

In other words, strong selective reflection function and light diffusion function are both provided in the liquid crystal layer. In accordance with the present invention, it is possible to minimize dependence on a viewing angle and to obtain bright display by light diffusion on an observing side without provision of a light diffusion plate on an outer side of the liquid crystal panel.

In the present invention, the phrase "rubbing alignment layer" means an alignment layer subjected to rubbing. And the phrase "rubbed alignment surface" means a surface of an alignment layer which is subjected to a rubbing treatment. This alignment layer can be formed by a roller method or another method, which has been normally used for preparation of TN-LCD, STN-LCD or another device. What is important is that the rubbing alignment layer has no purpose of twisting a liquid crystal layer at 240° as in STN-LCD.

In the present invention, a new alignment layer that exhibits a soft property in terms of the pencil hardness test is used as the alignment layer for the purpose of prevention against the "image-sticking". As to the alignment layer on the other substrate, any one of a non-alignment layer (a surface layer), a vertical alignment layer, a horizontal alignment layer and a rubbing alignment layer may be employed.

Next, in order to obtain display in the "high brightness" as the second problem simultaneously, a combination of the "alignment layer for prevention against image-sticking" and the "RVA" is used on the front side or the rear side.

In order to obtain a wide viewing angle as a property, the "RVA" is provided on the rear side, and the "alignment layer for prevention against image-sticking" is preferably provided on the front side.

Now, explanation of the structure for attaining the "high brightness" and the "wide viewing angle" in the present invention will be made. In an example, the rubbing alignment layer is provided on the rear side (the side opposite to an observer), and a horizontal alignment layer or a non-alignment layer, not subjected to a rubbing treatment is provided on the front side. Specifically, the front side may have only an ITO layer or an ITO layer with an insulating layer thereon. Additionally, a horizontal alignment layer may be provided on the ITO layer or the insulating layer.

When the rubbed alignment layer is provided on the front side, it is preferable to provide an outer diffusion layer. This is because specular reflection becomes too strong.

An "electrical insulation layer" made of metal-oxide may be provided in combination with the "alignment layer for prevention against image-sticking". This mode is preferable since a drive voltage can be reduced though providing no remarkably high brightness and since the occurrence of short circuit failure in the liquid crystal layer can be restrained compared to a case of having no alignment layer at both sides. CL-LCD in the mode capable of performing display in high brightness in accordance with the present invention is about 1.2-1.3 times in brightness and about twice in contrast ratio in comparison with performance of conventional devices. Now, explanation of specific examples and specific comparative examples will be made.

First, a substrate with a transparent conductive layer made of ITO was prepared to provide a substrate with RVA. After an electrical insulation layer was formed on an electrode forming side of the substrate, a solution of polyimide resin (manufactured by JSR Corp. Product No.: JALS-682-R3) was coated on the electrical insulation layer and was baked at 180° C. for 60 min and was subjected for a rubbing treatment. By such treatment, the resin layer had a layer thickness of about 500 Å and a pre-tilt angle of about 89°.

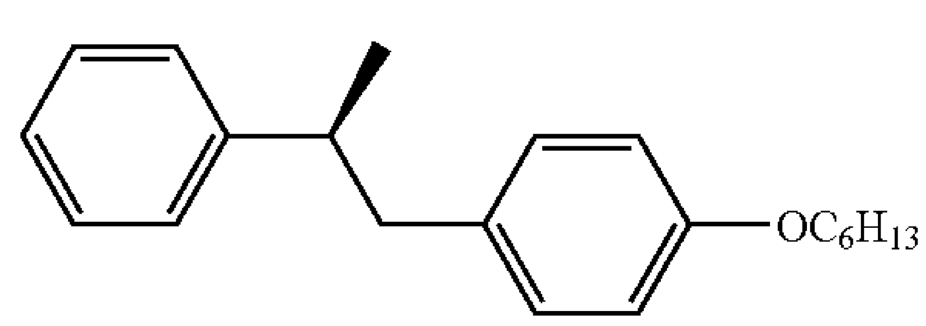
Additionally, in order to provide a substrate with a horizontal alignment layer like conventional devices, a solution of polyimide resin for liquid crystal elements, such as SE3840 (manufactured by Nissan Chemical Industries, Ltd.), and A2504 and A2710 (manufactured by Chisso Corporation) was coated on an electrical insulation layer of a substrate with ITO by a spin coat method, was dried at 60° C., and then was baked at 250° C. for 60 min. By such treatment, the resin layer having a layer thickness of about 600 Å was prepared.

Then, spacers of resin beads having a diameter of 4 μm were scattered on the substrates, and a peripheral sealing material made of an epoxy resin including a slight amount of glass fibers having a diameter of 4 μm was coated at 4 sides of the substrates excluding a portion as a liquid crystal injection port. Then, the two substrates were bonded to thereby prepare a liquid crystal cell. Such a production flow, i.e., each of the steps of preparation of substrates with ITO, patterning of ITO, forming of insulating layers, forming of alignment layers, printing of a peripheral seal, rubbing, scattering of spacers and bonding of two substrates is shown in FIG. **6**. Rubbing treatment may be carried out as in TN-LCD OR STN-LCD.

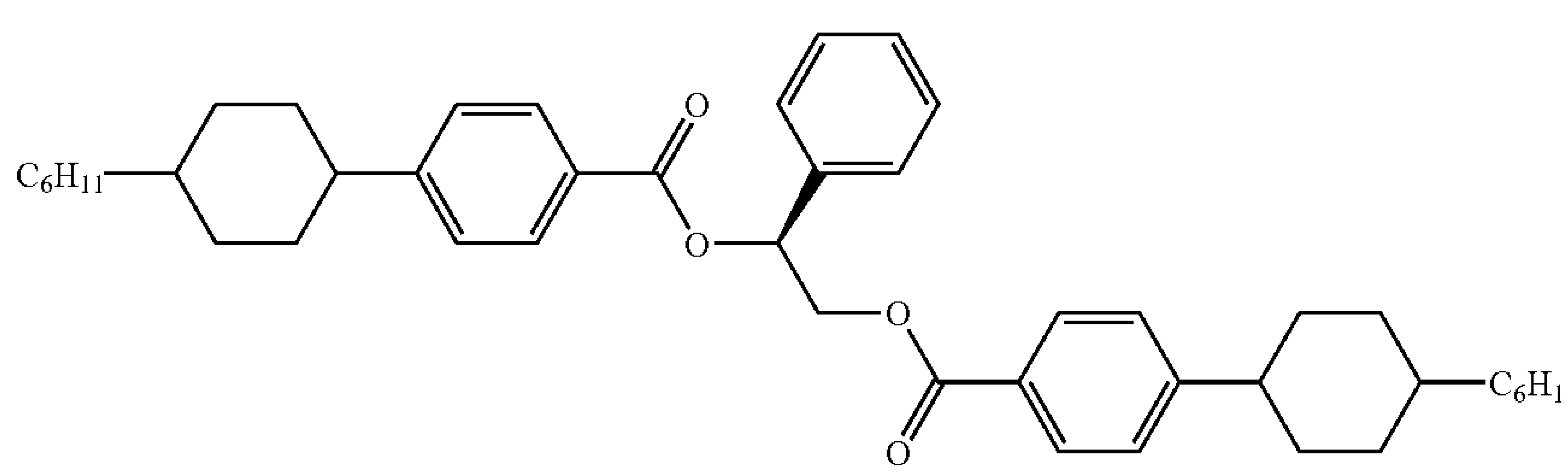
Next, as a chiral nematic liquid crystal, 5.1 parts of chiral agent indicated by Chemical Formula 1, 5.1 parts of chiral agent indicated by Chemical Formula 2 and 5.1 parts of chiral agent indicated by Chemical Formula 3 were mixed to 84.7 parts of nematic liquid crystal having T_c=87° C., Δn=0.231, $\Delta\epsilon$=16.5, viscosity η=32 mPa·s and relative resistivity=2×10^{11} Ω·cm. Thus prepared chiral nematic liquid crystal is referred to as a liquid crystal P. The helical pitch of the liquid crystal P was about 0.34 μm.

Additionally, as a second liquid crystal material, a chiral nematic liquid crystal (hereinbelow, referred to as the liquid crystal R), which comprises 70.8 parts of nematic liquid crystal "MJ00423" (manufactured by Merck Japan Ltd.: Tc=94.0° C., Δn=0.230, ϵ=15.0), 14.6 parts of chiral agent indicated by Chemical Formula 4 and 14.6 parts of chiral agent indicated by Chemical Formula 5, was prepared.

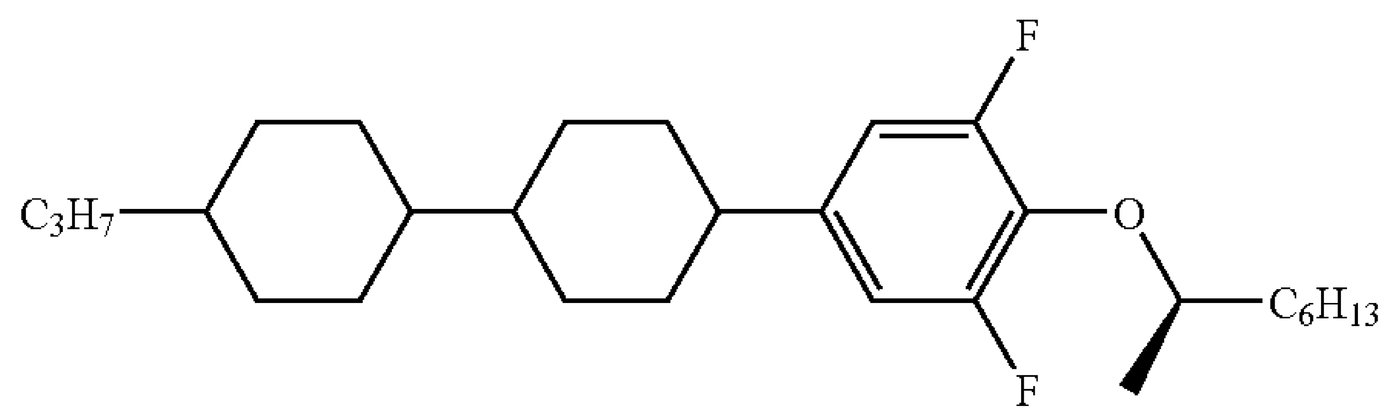
(1)



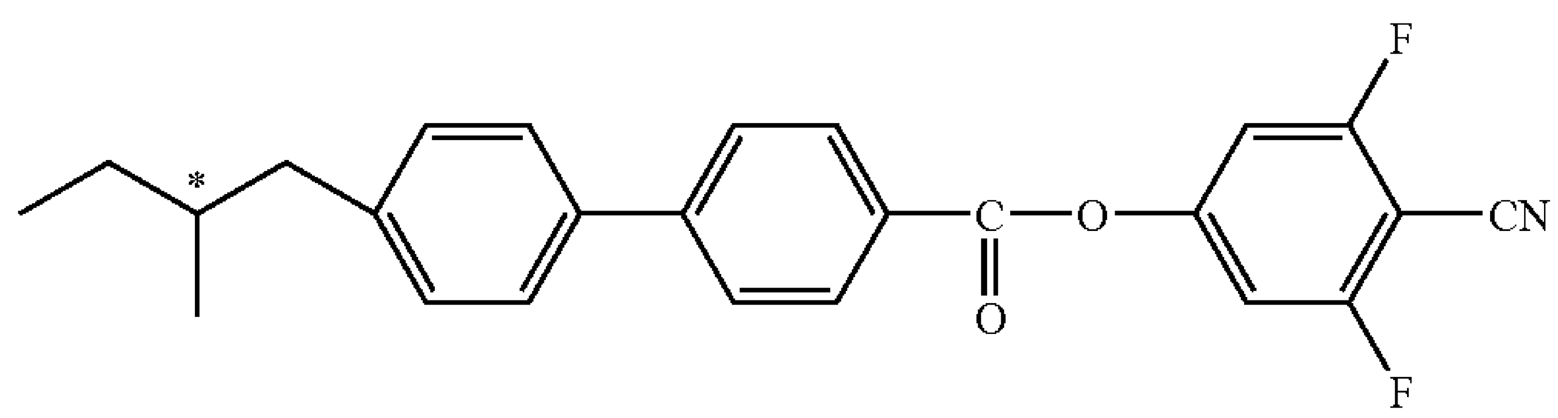
(2)



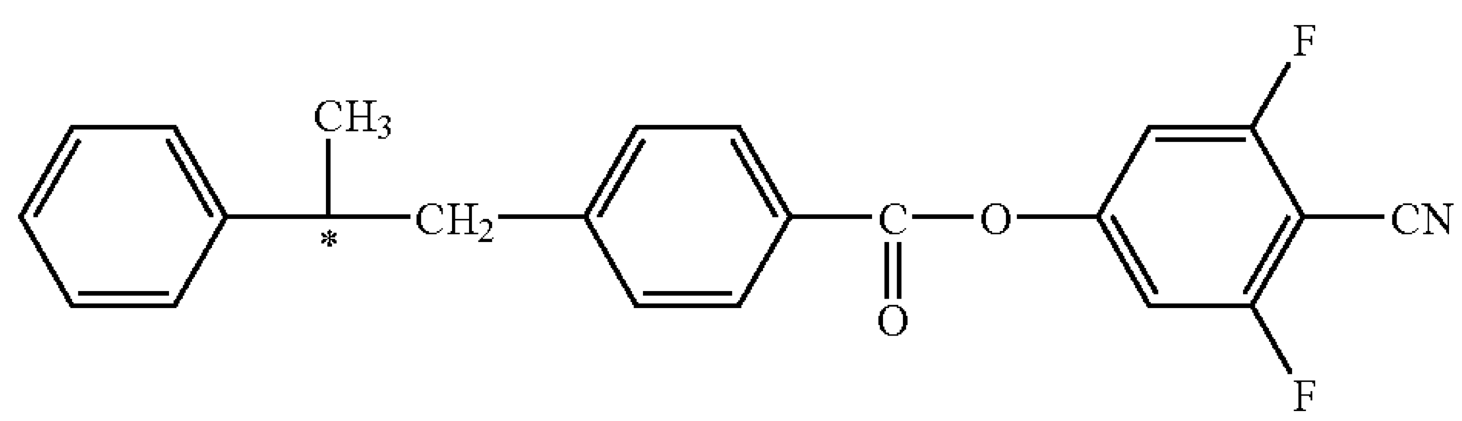
-continued



(3)



(4)



(5)

After the liquid crystal P was injected to the liquid crystal cell by a vacuum injection method, the injection port was sealed with a photocurable resin. The injected liquid crystal P was directly on the resin layers. In this case, the surface hardness of the resin layers was determined to be "B" or less in terms of pencil hardness. Further, a black paint was coated on an outer surface of a rear side substrate in the liquid crystal cell. Hereinbelow, Examples and Comparative Examples will be described.

EXAMPLE 1

CL-LCD was prepared according to the manufacturing method described before. The line space was 10 μm and the number of stripe electrodes was 4. Each resin layer as a boundary layer was formed by using a solution of polyimide resin RN-1256 manufactured by Nissan Chemical Industries, Ltd. wherein the layer thickness was about 600 Å. In the measurement of the surface hardness of the resin layer according to the before-mentioned test method, it was found to be "B". RN-1266 and RN-1286 which is used in Example 2 are a new material for an alignment layer, and the properties and so on are described in specifications provided by that company.

Then, a bipolar pulse of rectangular waveform (hereinbelow, referred to as a pulse A) having a pulse width of 900 ms and an effective value of 20 Vrms was applied to all pixels through electrodes of both substrate. Then, liquid crystal P became FC, and all the pixels exhibited a uniform black color. Then, a bipolar pulse of rectangular waveform (hereinbelow, referred to as a pulse B) having a pulse width of 100 ms and an effective value of 40 Vrms was applied by selecting electrode lines of the both substrates. The liquid crystal P at pixels to which the voltage was applied, became PL, and the pixels exhibited a selective reflection of green color.

As described above, a state that a portion exhibiting a selective reflection of green color and a portion exhibiting a black color were mixed in the same display surface, was provided. After the liquid crystal optical element was put in a constant temperature of 60° C. for 10 days, it was again taken out in an atmosphere of room temperature. The state of display at the time of taking out from the incubator was the same as that before putting into the incubator.

Next, the pulse A and the pulse B were alternately applied 3 times to all the pixels by selecting all electrode lines. When voltages were applied and stopped in the order of pulse A, pulse B, pulse A, each pixels exhibited a uniform black color (FC) having no difference of brightness. Further, when voltages were applied and stopped in the order of pulse B, pulse A, pulse B, each pixel exhibited a uniform selective reflection of green color (PL). Thereafter, even when the application of the pulse A or the pulse B was repeated several times, a uniform green color or black color having no difference of brightness was exhibited between pixels. As described above, in CL-LCD using the resin layers having a pencil hardness "B" or less, the occurrence of image-sticking could be suppressed.

EXAMPLE 2

A liquid crystal optical element was prepared by the same method as in Example 1 except that a solution of polyimide resin RN-1286 manufactured by Nissan Chemical Industries, Ltd. was used. The line space was 10 μm and the number of stripe electrodes was 160. The surface hardness of the resin layers was "3B".

First, initialization was performed by applying a relatively high voltage to liquid crystal corresponding to each pixel to render the liquid crystal to be HO; by eliminating the voltage in such state, and applying further a voltage which rendered the liquid crystal to be FC. After the initialization, a-line-at-a-time driving was performed in one round with 160 row electrodes and 160 column electrodes to display a character of "A", and then, the application of the voltage was stopped. As a result, a state that a character of "A" in a green color (PL) was displayed in a background of black color (FC), was provided. After the liquid crystal panel displaying a character of "A" was preserved in a incubator of 60° C. for about 1000 hours, it was again taken out in an atmosphere of room temperature. The state of display at the time of taking out from the incubator was the same as that before putting into the incubator.

Next, the liquid crystal to all the pixels was made to be FC by the same driving method as used for displaying a character of "A" before the preservation whereby a black image was provided in the entire display. Further, the liquid crystal to all the pixels was made to be PL as well, whereby the entire display became a state exhibiting a selective reflection of green color. Further, the liquid crystal to all the pixels was again to be FC, whereby the entire display provides a black display, and then, the application of the voltage was stopped. In this case, there was no difference of brightness between pixels, and the entire display exhibited a uniform black color. Thereafter, even when an attempt of providing a state of black display or a state of selective reflection was made several times, a uniform image having no difference of brightens could be obtained between pixels. In this Example too, the occurrence of image-sticking could be inhibited by using resin layers having a pencil hardness of "B" or less.

COMPARATIVE EXAMPLE A1

A liquid crystal optical element was prepared by the same method as in Example 1 except that a solution of polyimide resin SE-3840 manufactured by Nissan Chemical Industries, Ltd. was used as resin layers. The surface hardness of the resin layers in this example was "3H".

In the same manner as in Example 1, a state of that a portion exhibiting a selective reflection of green color and a portion exhibiting a black color were mixed in the same panel, was provided. The panel was put in a incubator of 60° C. for 10 days. Then, it was again taken out in a atmosphere of room temperature. The state of display was the same as that before putting into the incubator.

Next, the pulse A and the pulse B were alternately applied 4 times or more to all the pixels by selecting the all electrodes. When the pulse A and the pulse B were alternately applied in the order of pulse A, pulse B, pulse A, . . . , it was found that there was a difference of brightness between pixels and a uniform image could not be provided in the entire display even in a case that the entire display was in a black color, or a case that the entire display was in a green color (selective reflection). The difference of brightness took place between pixels which displayed a black color and pixels providing the selective reflection before the preservation in the incubator.

Even when voltages were applied in the order of pulse B, pulse A, pulse B, . . . after the panel was taken out from the incubator, the entire display did not provide a uniform image. Further, after a lapse of 5 days, there was no change in the state of display. Thus, image-sticking took place in the case that the surface hardness of the resin layers in contact with the liquid crystal P was "3H".

COMPARATIVE EXAMPLES A2, A3 AND A4

Liquid crystal optical elements were prepared in the same manner as in Example 2 provided that the kind of a solution of resin used for forming resin layers was changed. The solution of resin by CHISSO CORPORATION is for conventional TN or STN. In Comparative Example A4, no alignment layer was formed Then, a character of "A" was displayed by the same driving method as in Example 2, and then, the application of the voltage was stopped. The liquid crystal in a background portion exhibited a black color (FC), and the liquid crystal in a portion corresponding to a character of "A" exhibited a green color (PL) After the liquid crystal panel was preserved in a incubator of 60° C. for about 1000 hours, it was again taken out in an atmosphere of room temperature.

The entire display was made to be a black image by the same driving method as used for displaying "A" before the preservation in the same manner as Example 2. Further, the liquid crystal to the entire pixels was made to be PL, and the entire display was to be a state of selective reflection of green color. Further, the liquid crystal to the entire pixels was again to be FC, whereby the entire display provided a black image, and then, the application of the voltage was stopped.

Then, a degree of recognition of a image of "A" after a long time preservation, namely, a degree of the occurrence of image-sticking was examined for each solution of resin used. Further, the surface hardness of the resin layers by each of the solution of resin was measured by the before-mentioned method. Table 1 shows the surface hardness of the resin layers and a degree of image-sticking in each Example. In Table 1, "○" indicates a state that the character of "A" can not be observed at all, "X" indicates a state capable of being recognized, and "XX" indicates a state that it can be recognized strongly. Further, even after a lapse of 5 days, there was no change in the degree of image-sticking in each of the liquid crystal panels.

TABLE 1

Example	Kind of solution of resin (Product code and producer)		Surface hardness	Degree of image-sticking
1	RN-1266	Nissan Chemical Industries, Ltd.	B	○
2	RN-1286	Nissan Chemical Industries, Ltd.	3B	○
A1	SE-3840	Nissan Chemical Industries, Ltd.	3H	X
A2	A-2504	CHISSO CORPORATION	3H	X
A3	A-2710	CHISSO CORPORATION	3H	X
A4	(Nil) Only ITO		>6H	XX

As shown in Table 1, image-sticking takes place when the surface hardness of the resin layers is "3H" or the like. However, no image-sticking takes place when the surface hardness is relatively low as "B" or "3B".

In the above-mentioned Examples 1 and 2, the surface hardness of the boundary layers were respectively "B" and "3B". The resin layers having a surface hardness within "B" to "3B" can be formed by adjusting a relative amount of the solution of resin used in each Example and mixing it.

Further, instead of polyimide, a predetermined compound may be selected from a polymer material in consideration of the durability to liquid crystal, the temperature properties, long time stability, easiness in forming the resin layers and so on.

In each of the above-mentioned Examples, a case that a resin layer is provided between the entire surface of the transparent electrode and the liquid crystal layer is shown. Even in a case that the resin layer is provided between a part of the transparent electrode and the liquid crystal layer, image-sticking can be prevented in a range where the resin layer is provided.

Since it is considered that the image-sticking takes place by that the orientation of liquid crystal in a state of preservation affects liquid crystal molecules fixed at the interface, it is preferable that the resin layer having a lower hardness is directly on the liquid crystal.

EXAMPLE 3

A liquid crystal panel was provided by the same method as Example 1 except that only a resin layer formed on a rear substrate was subjected to a rubbing treatment. As in Example 1, a black paint for delustering was applied on an outer side of the rear substrate. A drive pulse was applied across electrode leads (terminals) of both substrates. After a bipolar pulse of rectangular waveform having a pulse width of 20 msec and an effective value of 40V rms was applied, the drive pulse was cut off. Consequently, the liquid crystal layer that confronts to the entire display screen of the liquid crystal panel was instantly transformed into PL. Then, the liquid crystal layer was rendered into PL with normal reflection slightly added until about 30 sec were passed. After lapse of further several minutes, this state became stable at substantially the brightest level. There was no change even after the liquid crystal layer was left for five days.

Next, after a bipolar pulse of rectangular waveform having an effective value of 20V rms was applied, the drive pulse was cut off. Consequently, the liquid crystal layer was instantly rendered into black in the entire plane (FC), and then the liquid crystal layer was rendered to be slightly bright black with selective reflection color light slightly added. There was no change in this state even after the liquid crystal layer was left for five days.

In addition, the PL state of the liquid crystal panel was observed under illumination by a fluorescent lamp, which was incident on the panel at an inclination angle of 30° with respect to the normal line of the display screen. The observation showed that there was no extremely strong selective reflection light in the outgoing direction having an inclination angle of 30° on a side opposite to the incident light. Without providing a light diffusion plate on an outer side of the liquid crystal panel, bright display was able to be obtained from every direction except for normal reflection. However, the contrast ratio drastically lowered since black display was rather too bright.

EXAMPLES 4-6

Now, Examples 4, 5 and 6 as examples and comparative examples will be described. In the respective examples, the liquid crystal R was employed. In the present invention, a combination of the "alignment layer for prevention against image-sticking" and another material, the presence and absence of rubbing, and the position of the front side and the rear side may be selectively determined.

With respect to the display state in each of the examples, a value in actual measurement or a value in estimation are shown on the right-hand side in the following Tables. Brightness is indicated by Y values of luminous reflectance. With respect to drive voltage, the driving voltage at which the contrast ratio is maximum when a-line-at-a-time driving was performed are indicated in the respective Tables. The electrical insulation layer employed in the present invention is metal-oxide including at least one element selected among silicon, titanium, zirconium, and antimonate. In each of the following Examples 6-6 and 6-7, an electrical insulation layer, which comprises metal-oxide of SiO_2/TiO_2=50:50 (wt %), was prepared so as to have a thickness of 40 nm for use. As other metal-oxide, $SiO_2/TiO_2/ZrO_2$=40/50/10, $SiO_2/TiO_2/ZrO_2/Sb_2O_5$=25/50/10/15, and the like may be employed.

In the Tables, "*" means that rubbing treatment was performed, and "NON" means that the liquid crystal layer is in direct contact with ITO or a layer of metal-oxide without providing of a so-called liquid crystal alignment layer. In FIG. **7**, "NS" is an abbreviation having meaning of Non Sticking (alignment layer for prevention against image-sticking). And "MIC" indicates an insulating layer made of metal oxide. The mark "◎" represents the quality level of display of no "image-sticking". And the relative evaluation is shown by the order of marks such as "X", "Δ", "○" and "◎".

Further, above-mentioned RN1266 in Example 1 is used in replace of RN1286. The same evaluation is resulted. Both RN1286 and RN1266 are a polymer that satisfies the condition of eighth aspect of present invention.

TABLE 2

NO.	FRONT SIDE	REAR SIDE	DRIVE-VOLT	DISPLAY STATE	STICKING
4-1	* RVA	(NON)	16 V	MIRROR REFLECTION	X
4-2	* RVA	SE3840	19 V	MIRROR REFLECTION	Δ
4-3	* RVA	RN1286	19 V	MIRROR REFLECTION	○
4-4	* RVA	RVA	19 V	MIRROR REFLECTION	Δ

TABLE 3

NO.	FRONT SIDE	REAR SIDE	DRIVE-VOLT	BRIGHTNESS	CONTRAST	STICKING
5-1	(NON)	* RVA	16 V	50%	10	X
5-2	SE3840	* RVA	19 V	50%	10	Δ
5-3	RN1286	* RVA	19 V	45%	10	○
5-4	RVA	* RVA	19 V	50%	10	Δ
5-5	A2710	* A2710	19 V	50%	3	Δ

TABLE 4

NO.	FRONT SIDE	REAR SIDE	DRIVE-VOLT	BRIGHTNESS	CONTRAST	STICKING
6-1	(NON)	(NON)	16 V	40%	10	X
6-2	SE3840	SE3840	22 V	40%	7	Δ
6-3	A2710	A2710	22 V	37%	5	Δ
6-4	A2504	A2504	22 V	40%	7	Δ
6-5	EN1286	RN1286	20 V	32%	6	⊚
6-6	RN1286	(NON)	18 V	36%	5	○
6-7	(NON)	RN1286	18 V	36%	5	○

EXAMPLE 7

By using the respective examples, a public information display apparatus, such as a signboard, a price display unit and a menu display unit, can be provided. As an example, it is shown in FIG. **8** how the menu display unit performs display. The menu display unit is a superior display apparatus, which basically has a high resolution, is capable of performing character display and clear graphic display simultaneously, is bright, has a wide viewing angle and performs a display function having a memory effect. When the menu display unit is used at a restaurant, the menu display unit with a built-in battery is put on each table. A customer can pick up a menu display unit to see the menu on the display screen. Respective menu display units **1** are controlled by a computer **20**A in a shop through a wireless transmission system, such as infrared data communication, wireless LAN, PHS and Bluetooth. The computer is connected to a computer **20**B in a central supervisory center **30** through a dedicated line or internet (see FIG. **9**).

By such arrangement, it conveniently becomes possible to grasp a state of accepting order in real time. It is easy to modify the contents of a menu, depending on seasons, days and times, weather and other factors. It is possible to optimize inventory control. Additionally, it becomes possible to display advertisement in real time.

Further, it is possible to provide the menu so as to match with the tooth of respective customers and to perform display for bills. The menu display unit is appropriate for ordinary restaurants and meal services required at hotels, on trains, on airplanes and on others, which require interaction with customers.

It is in particular preferable that the menu display unit with a liquid crystal optical element according to the present invention applied thereto is incorporated into a system suited to on-line central control, since the display unit can produce a display function with a memory effect (an energy saving property) and a good display property.

It is shown in FIG. **10** how the price display unit performs display. Lines or graphics as display information can be presented in black on a background color having a selectively reflected color. The price display unit is superior in recognizability in comparison with conventional LCDs and can be activated with a memory effect.

The liquid crystal optical element shown in each of the above-mentioned Examples has such structure that two substrates have respectively a plurality of electrodes. However, a structure that either of the substrates has an electrode which is divided into a plurality of portions and the other has a non-divided common electrode (a sheet-like electrode) may be used.

In the test method of the present invention, a state of standing means that a state of display is maintained as it is in a predetermined atmosphere without applying a driving voltage. In this case, inspection for image-sticking can be conducted in a shorter time than the before-mentioned Examples by adjusting external circumstances such as temperature. For example, in conducting sampling inspection for each lot or a periodical inspection of evaluating process in mass production, a result can be obtained preferably in a short cycle.

Further, the present invention is applicable not only to a liquid crystal display element for performing dot matrix driving but also a liquid crystal optical element for performing segment display type and static driving. Further, in the liquid crystal optical element in the present invention, the liquid crystal may be a cholesteric liquid crystal.

In accordance with the present invention, the occurrence of image-sticking can be prevented by providing a resin layer having a surface hardness of B or less in a pencil hardness test method, between a part of or the entire surface of the electrode of at least one substrate and the liquid crystal.

In accordance with the present invention, the helical axes in the liquid crystal can be induced to align in a direction perpendicular to the substrate plane to obtain a high reflection state to incident light. On the other hand, the viewing angle becomes relatively wide in the vicinity of the interface between the first substrate and the liquid crystal layer since there are dispersion in the direction of the helical axes in the liquid crystal due to lack of surface interaction, for example anchoring strength.

In other words, a strong selective reflection function and a light diffusion function are both provided in the liquid crystal layer. In particular, it is possible to minimize dependence on the viewing angle and to obtain bright display by a light diffusion property on an observing side without providing a light diffusion plate on an outer side of the liquid crystal panel.

Further, the liquid crystal optical element of the present invention can be used for a public information display apparatus, a display device for a portable equipment, a display device for an equipment of measurement, a display device for a private electronic equipment and so on. Further, a display of high quality having a memory effect can be provided.

The entire disclosures of Japanese Patent Application No. 2001-285979 filed on Sep. 19, 2001, Japanese Patent Application No. 2000-402045 filed on Dec. 28, 2000 and Japanese Patent Application No. 2001-372802 filed on Dec. 6, 2001 including specifications, claims, drawings and summaries are incorporated herein by reference in their entireties.

What is claimed is:

1. A chiral nematic liquid crystal optical element, comprising:

a pair of substrates with transparent electrodes;

a liquid crystal layer having a memory property interposed between the substrates;

a first resin layer which is provided on one of the transparent electrodes, said first resin layer having a rubbed vertical alignment surface in contact with the liquid crystal layer; and

a second resin layer which is a resin layer selected from the group consisting of a surface layer which has not been subjected to an alignment treatment by rubbing, a vertical alignment layer or a horizontal alignment layer, said second resin layer being provided between the liquid crystal layer and the other of the transparent electrodes,

wherein said liquid crystal layer exhibits a planar state and a focal conic state; and

wherein the second resin layer has a surface hardness of B or less in a pencil hardness test.

2. The liquid crystal optical element according to claim **1**, wherein the first resin layer is provided only on the substrate on a side opposite to an observing side.

3. The liquid crystal optical element according to claim **1**, wherein said focal conic state produces a scattering of incident light.

4. The liquid crystal optical element according to claim **1**, wherein said planar state produces a selective reflection of incident light.

5. The liquid crystal optical element according to claim **1**, which is a color display.

6. The liquid crystal optical element according to claim **1**, wherein said second resin layer comprises a polyimide which has been baked.

7. The liquid crystal optical element according to claim **1**, further comprising

a first electrically insulating layer which is coated on at least one of the electrodes and a second electrically insulating layer which is coated on the other electrode; and

wherein said first and said second resin layer are coated on said electrically insulating layer.

8. The liquid crystal optical element according to claim **1**, wherein said second resin layer is a surface layer which has not been subjected to an alignment treatment by rubbing.

9. The liquid crystal optical element according to claim **1**, wherein said second resin layer prevents image-sticking.

10. The liquid crystal optical element according to claim **1**, wherein the liquid crystal layer exhibits reflection characteristics as if the liquid crystal layer is a mirror.

11. The liquid crystal optical element according to claim **1**, wherein said rubbed vertical alignment surface does not twist the liquid crystal at 240°.

12. The liquid crystal optical element according to claim **1**, wherein said second resin layer consists of a resin.

13. A chiral nematic liquid crystal optical element, comprising:

a pair of substrates with transparent electrodes;

a liquid crystal layer having a memory property interposed between the substrates;

a metal-oxide layer provided on at least one of the transparent electrodes;

a first resin layer which is provided on one of the transparent electrodes,

said first resin layer having a rubbed vertical alignment surface in contact with the liquid crystal layer; and

a second resin layer which is a resin layer selected from the group consisting of a surface layer which has not been subjected to an alignment treatment by rubbing, a vertical alignment layer or a horizontal alignment layer, said second resin layer being provided between the liquid crystal layer and the other of the transparent electrodes,

wherein said liquid crystal layer exhibits a planar state and a focal conic state; and

wherein the second resin layer has a surface hardness of B or less in terms of a pencil hardness test.

14. The liquid crystal optical element according to claim **13**, wherein the paired transparent electrodes have a drive voltage of 20V or less applied thereacross.

15. The liquid crystal optical element according to claim **13**, wherein said second resin layer comprises a polyimide which has been baked.

16. The liquid crystal optical element according to claim **13**, further comprising

a first electrically insulating layer which is coated on at least one of the electrodes and a second electrically insulating layer which is coated on the other electrode; and

wherein said first and said second resin layer are coated on said electrically insulating layer.

17. The liquid crystal optical element according to claim **13**, wherein said second resin layer is a surface layer which has not been subjected to an alignment treatment by rubbing.

18. The liquid crystal optical element according to claim **13**, wherein said second resin layer prevents image-sticking.

19. The liquid crystal optical element according to claim **13**, wherein the liquid crystal layer exhibits reflection characteristics as if the liquid crystal layer is a mirror.

20. The liquid crystal optical element according to claim **13**, wherein said rubbed vertical alignment surface does not twist the liquid crystal at 240°.

21. The liquid crystal optical element according to claim **5**, wherein said second resin layer consists of a resin.

* * * * *